Influence of leaf area development of early and mid-early maturity varieties of silage maize on dry matter yield and forage quality

Dissertation

zur Erlangung des akademischen Grades

Doktor rerum agriculturarum

(Dr. rer. agr.)

Institut für Pflanzenbauwissenschaften, Landwirtschaftlich-Gärtnerische Fakultät

Humboldt-Universität zu Berlin

vorgelegt von: Msc, Agriculture, Patrick Nixon Edoka

geboren: 04.11.1958, Lira – Uganda

Präsident der Humboldt-Universität zu Berlin

Prof. Dr. Hans Jürgen Prömel

In Vertretung

Dekan der Landwirtschaftlich-Gärtnerischen Fakultät

Prof. Dr. Dr. h. c. Uwe Jens Nagel

Gutachter:

1. Prof. Dr. Karlheinz Richter
2. Prof. Dr. Frank Ellmer

Datum der Verteidigung: Berlin, 27.01.2006

Abstract

Knowledge of leaf area development of silage maize varieties during the vegetation period is useful in the characterisation of the maturity conditions of plants and in the evaluation of new varieties. Leaf area, which is a function of leaf number and leaf size may affect yield and quality parameters of silage maize at varying levels, depending on the environmental conditions under which the crops are grown. One of the criteria for obtaining good quality forage is prognosis for optimum harvest time. Two experiments were conducted in 2002 and 2003 at Berge research station, belonging to the Institute of Crop Science (Faculty of Agriculture and Horticulture, Humboldt-University Berlin) with the aim to assess how silage maize varieties of maturity group early and mid early differ in LAI, leaf area development, specific leaf area, what differences exist between the two methods used to measure LAI. Considering yield and forage quality, under the condition of location Berge, with limited water availability, varieties with fewer leaves (13-16) may be suitable. To maintain the whole plant dry matter content within the optimum range (30-35%), especially under drought condition, harvest time must fall within the period when at least a minimum of two leaves below the cob leaf are still green.

Key words: Silage maize, maturity group, yield, forage quality, leaf area index (LAI)

Zusammenfassung

Kenntnisse zur Blattflächenentwicklung von Silomaissorten während der Vegetationsperiode sind erforderlich, um die Ausreife der Pflanzen charakterisieren und neue Sorte bewerten zu können. Die Blattfläche ist eine Funktion von Blattzahl und Blattfläche und kann den Ertrag und die Futterqualität von Silomais in Abhängigkeit von den Umweltbedingungen in unterschiedlichem Ausmaß variieren. Ein maßgebliches Kriterium für das Erreichen einer guten Futterqualität ist die Prognose des optimalen Erntetermins. In den Jahren 2002 und 2003 wurden zwei Experimente am Standort Berge des Institutes für Pflanzenbauwissenschaften (Landwirtschaftlich-Gärtnerische Fakultät der Humboldt-Universität zu Berlin) durchgeführt, um zu zeigen, wie sich Silomaissorten der Reifegruppen früh und mittelfrüh im Blattflächenindex, in der Blattentwicklung sowie spezifischen Blattfläche unterscheiden und welche Unterschiede zwischen zwei Messmethoden zur Bestimmung des Blattflächenindexes bestehen. Unter Beachtung von Ertrag und Futterqualität haben sich bei limitiertem Wasserangebot unter den gegebenen Standortbedingungen Sorten mit einer geringeren Anzahl von Blattgenerationen (13 bis 16) als geeignet erwiesen. Um Trockenmassegehalte in der Gesamtpflanze im optimalen Bereich von 30 bis 35 % im Erntegut garantieren zu können, sollte Silomais speziell unter trocken-heißen Abreifebedingungen dann geerntet werden, wenn mindestens zwei Blätter unterhalb des Kolbenansatzes noch grün sind.

Schlüsselworte: Silomais, Reifegruppe, Ertrag, Futterqualität, Blattflächenindex

Content

List of abbreviations

AM	Arithmetic mean
ADF	Acid detergent fiber
BBCH-stages	Phenological development stage code system
CHU	Corn heat unit
CV	Core variety
DM	Dry matter
Elos	Enzyme soluble organic substance [%]
fIPAR	Fraction of photosynthetically active radiation intercepted by the canopy
GLAM	Green leaf area at maturity
GDD	Growing degree days
HU	Heat unit
LAI	Leaf area index
LSD	Least significant difference of t-test
LSV	Landessortenversuch (regional variety test)
MGLA	Total plant leaf area
MTA	Mean tilt angle
NDF	Neutral detergent fiber
NEL	Netto energy lactation
NIRS	Near-infrared spectroscopy
RUE	Radiation use efficiency
PAR	Photosynthetically active radiation
PEP	Phosphoenolpyruvate
PNUE	Photosynthetic nitrogen-use efficiency
PPFD	Photon flux density
SLA	Specific leaf area
SLN	Specific leaf nitrogen
TAGPM	Temperature sum by L'Association Générale des Producteurs de Maïs
WPC	Whole-plant corn
VIVO DOM	In vivo digestibility of organic matter
X	check variety
XF	Crude fibre content [%]
XP	Crude protein content [%]

1 Introduction and aim of the experiment

Maize is one of the widely cultivated crops in the world, with great importance, both in industrial and developing countries. Because of this, continuous and considerable research work is directed not only towards improving its production potentials, but also to know the interaction of its production with the environment and effects (EDER & WIDENBAUER 2003). Current enviromental concerns justify renewed evaluation of crop management strategies that offer promise for maintaining or increasing productivity while reducing negative environmental impacts, through integrated agriculture (LÜTKE ENTRUP et al. 1996, 1998). Genetic constituents and environmental factors affect the production of maize, as in all other cultivated crops. Climatic conditions play a vital role in the growth and development of maize, affecting the length of the vegetation periods, thereby the type of maturity group to be grown in a given zone (SCHUPPENIES & WATZKE 1985). In so-called favourable conditions, maize gets the necessary climatic requirements such as relatively high temperature (optimum) and precipitation for a rapid growth, good maturity with high yield (HEIN 2002). However, in marginal climatic conditions, one or more of the climatic requirements are often not met. Marginal conditions, such as late freezing into the year, which does not only interfere with date of sowing, but also minimum soil temperature required for seed germination may not be attained in time early freezing in autumn, that increases the risk of normal maturity and harvest, especially of varieties with longer vegetation period like the stay-green type and reduced sun-shine hours during the vegetation period due to bad weather conditions are to be taken into consideration. Unfavourable environmental conditions at flowering in maize can cause cessation of ear development and ear abortion (TOLLENAAR 1977, JACOBS & PEARSON 1991).

In cooler regions of Central and West Europe, the use of maize as a forage crop has drastically increased in the last three decades (MORENO-GONZALEZ et al. 2000). The total area under maize cultivation in Germany has seen a slight increase in 2003, after a downward slope since 1997. There was a more than 6.4 % increase in silage maize grown in 2004 than in the previous year (Statistisches Jahrbuch 2004). Comparing to other European Union states engaged in maize production, 29 % of the overall cultivated area in Germany was under silage maize cultivation, only second to France with 41 % (from 1998-2003). Selection of genotypes (varieties) that would suit particular conditions of a location is a continious process, not only in maize but also in overall crop production. In the northeast plain of Germany for instance, water deficit during the vegetation period of maize is a common phenomenon which affects both dry matter yield and forage quality of corn. Generally, the accumulation of biomass by crops results from the amount of incident photosynthetically active radiation (PAR) intercepted by the canopy and from the efficiency with which the intercepted PAR is converted into dry matter. Dry matter accumulation is closely associated with leaf area development. The development of leaf area in turn is a function of both leaf size and leaf numbers. These factors may change differently depending on the genetic material (varieties) involved and the environment in which the plants are grown. The expansion and duration of green leaf area determines the fraction of incident radiation intercepted by the crop (ANDRADE et al. 2000, OTEGUI & ANDRADE 2000).

In Germany only varieties, which have successfully undergone a two years Bundessortenamt test and have been in the variety list or were released from other European Union countries are grown (Bundessortenamt 2003). In the variety list of 1999 for example were 51 early, 80 mid-early and 14 mid-late varieties totalling 145. More than 226 varieties are in the general EU variety catalogue and therefore may be used. These varieties are again released to regional variety trial research stations (LSV), whereby they are tested for three years before they are finally released for cultivation (in the market). The results from regional variety tests serve as a basis for recommendation of silage maize grown in specified locations. In this experiment some of the earlier recommended silage maize varieties (early and mid-early) for Brandenburg region were used (KÖHN 2002).

Information on LAI of forage maize varieties are important in order to characterize the maturity condition of residual parts of the plant (stems and leaves). Many methods exists to measure LAI during vegetation period (HAMMER et al. 1998, ŠESTÁK et al. 1971). The aim of this experiment was to use the leaf parameters (LAI, LA) of the various forage maize maturity groups measured by two methods, manual and LAI 2002, to present the variability in the development of leaf area of the different maturity groups during the vegetation period and between the years. Knowledge of the maturity condition of the leaves and loss of assimilation area during the vegetation period between the years and especially in a location with limited water availability like location Berge will help to characterize the suitability of certain varieties for such a location. The regional prognosis model (RATH et al. 2002) helps to estimate the optimum harvest time for silage maize. However, uncertainity in estimating the maturity time due to uncertainity in the changing weather conditions like drought stress and heat do exist. Additional criteria on leaf status at silking and post anthesis that may influence dry matter yield and dry matter content under conditions of drought stress, thereby affecting harvest time, can be the additional information on the prognosis for optimum harvest time of silage maize. The experiments also seek to answer such questions like:

- How do maize varieties of early and mid-early maturity groups differ in LAI and leaf area development?
- What differences exist between the two methods used to measure LAI (manual and LAI 2000)?
- What are the differences in SLA between the maturity groups and year?
- Does stay-green have advantage over non-stay green?
- What influence has LA of silage maize on yield and forage quality parameters?

2 Literature

2.1 Classification and selection of maize varieties

Due to the unequal maturity of cob and residual plant (leaf/stem) maize varieties fall in two major categories. Maize varieties whose cobs mature faster than residual plants (stay-green) and varieties whose residual mature faster than the cob. Until 1998 maturity classification of silage maize by the Federal Variety Authority (Bundessortenamt) was done solely through dry matter content of the cob (HARTMANN & GEIGER 2001). However with the introduction of stay-green varieties, the view on exclusive maturity assessment of maize silage varieties through cob has changed, because it was no more satisfactory. Former classification assessed energy density only through cob portion. The digestibility of residual plant part (leaf/stem) was not taken into account. Current classification system follows maturity grade of varieties after whole-plant dry matter content (RATH 2002).

In accordance with the FAO nomenclature all maize varieties fall within numbers 100-900 (ZSCHEISCHLER et al. 1990). Maize varieties are divided into maturity groups according to the length of time required from sowing to maturity. These groups are labelled as early, mid-early, mid-late and late. Within each group varieties are once more sub-divided with the help of number 10. Under Germany conditions the difference of 10 FAO numbering gives approximately 1-2 days difference in maturity, that is, 1-2 % in dry matter content in corn maize at the time of harvest. A variety with FAO number 280 matures under Germany conditions approximately 5-8 days later than one with FAO number 230. That means by harvesting both varieties on the same day the dry matter content of corn varieties with FAO number 280 would be nearly 5-8 % lower. This also explains the fact that the same type of variety grown in other countries (under various environmental conditions) is differently grouped.

Climatic (weather) conditions seem to dictate on the selection of maize genotypes (varieties) for a given area temperature is one of the most limiting factors in maize production across locations as it affects the growth rate and development of the plant. On the other hand in Brandenburg region (north east plain of Germany), where this experiment was conducted, water deficit (drought), leads to low dry matter yield and low forage quality of silage corn (SCHMALER et al. 2003), most crucial is the distribution of water during vegetation period and water deficit during silking (SCHMALER & RICHTER 2002). Water stress occuring during vegetative and tasselling stages reduced plant height as well as leaf area development. Vegetative and yield parameters were significantly affected by water shortage in the soil profile due to omitted irrigation during the sensitive tasselling and cob formation stages (ÇAKIR 2004). On soils with low available water capacity maize reached highest yields (120 dt ha^{-1} up to 129 dt ha^{-1}) if the first N-application was applied at a plant height of 15 cm. A lower plant density stimulated yields on soils with low available water capacity also (STICKSEL et al. 1996). Selection for drought tolerant varieties or varieties with faster rate of leaf development (rapid canopy closure) which would enable maximum earlier interception of light energy, photosynthesis, biomass production and dry matter accumulation would be appropriate (WESTGATE et al. 1997). Otherwise, if maintaining green leaf area in maize under drought (water deficit) condition should improve yield, then selection for stay-green varieties would be another alternative (BORRELL et al. 2000 a, b). However to reduce the risk on yield and quality of forage maize that might be caused by adverse weather conditions and to utilise any technological advantages of the varieties a combination of maturity groups and maturity types are grown. Under Brandenburg condition it would be suitable to grow 2/3 mid-early stay-green varieties to 1/3 early synchronic maturity varieties (BARTHELMES & KRÜGER 2002). In order to improve on whole plant (total) digestibility and resistance to *fusarium ssp.* of silage maize selection for varieties with varying maturity positions of generative and vegetative parts of silage maize (asynchronic maturity of corn and residual plant) is being intensified in recent years (STEINHÖFEL 2000). Because non grain portion of the plant may represent over 50 % of the total dry matter in corn silage, variety (hybrid) differences in chemical composition and ruminal fermentability of the stover portion of the plant may account for important nutritional differences in corn hybrids (HUNT et al. 1989).

In considering maize varieties for silage purposes characteristics like yield, yield stability and above all, forage quality, which includes starch content, energy content and digestibility of the residual plant is very important. DEINUM & BAKKER (1981) found digestibility differences among corn hybrids. Hybrid differences in dry matter yield have been documented (FAIREY 1980, DEINUM 1988). DEINUM (1988) concluded that yield and quality should be taken in consideration when selecting hybrids for forage. The introduction of Near-Infrared-Reflectance-Spectroscopy (NIRS) has enabled further analysis of contents of other forage quality components like crude fibre, crude protein, ADF, NDF or enzyme soluble carbohydrates (SHENK & WESTERHAUS 1994). Other parameters important in selection of varieties include resistance to parasitic diseases like *Helminthosporium turicum*, *Ustilago maydis* and pests like *Oscinella frit*, *Ostrinia nubilalis* that can cause negative effects on yield and quality (HURLE et al. 1996). Varieties susceptible to strong wind and heavy rainfall normally suffer stem bends and stem break off, a phenomenon referred to as 'green-snapping'. At a period of plant growth nearing flowering this phenomenon could result in damage to plants, hence influencing overall yield and quality components (EDER & WIDENBAUER 2003). The selection of maize varieties and the timing of harvest are important management considerations for dairy and livestock operations. Adverse spring conditions often push planting dates for corn past the optimum for grain and sometimes silage production (DARBY & LAUER 2002). Achieving high dry matter yield from whole-plant corn (WPC) and high milk production from cows fed WPC depends on the harvesting of the corn at the proper stage of maturity (BAL et al. 1997). Agronomic trials (GANOE & ROTH 1992) have shown that dry matter yields of whole-plant corn are maximized by harvesting at two-thirds milkline to black layer stages. At an immature stage of harvest, fiber oncentrations are highest, which lowers the energy density of whole-plant corn (HUNT et al. 1989). At a mature stage of harvest, digestibility of the stover is reduced (WIERSMA et al. 1993), which may lower the energy density of whole-plant corn. Harvest of whole-plant corn at a mature stage may also increase whole kernel passage and lower starch digestibility (HARRISON et al. 1996). Therefore stover and starch digestibility should be considered in most equations that predict energy value from whole-plant from ADF concentration (MAHANNA 1995). Poor starch fill (and grain yield) can cause photosynthetic energy to remain as sugar in the stover and leaves, thus diluting fiber content but not yielding the expected net energy (COORS et al. 1997, FAIREY 1983, DEINUM & KNOPPERS 1979).

2.2 Leaf area

Leaf area and light distribution are important input parameters in canopy photosynthesis modeling. The ability to predict leaf area and leaf area index is crucial in crop simulation models that predict crop growth and yield (HAMMER et al. 1998). The amount and vertical distribution of leaf area are essential for estimating radiation interception for canopy photosynthesis modeling (BOEDHRAM et al. 2001, SIVAKUMAR & VIRMANI 1984). Vertical distribution of leaf area has often been constructed from leaf areas per horizontal layers based on height (ACOCK et al. 1978), cumulative leaf area index (NORMAN 1978, GOUDRIAAN 1986, PATTEY et al. 1991) and leaf number (CONNOR et al. 1995). In studies of leaf area in maize, area of individual leaves is usually calculated from leaf length (LL) and leaf width (at the wid est point LW) as follows (MONTGOMERY 1911):

Individual leaf area = 0.75*LL*LW [Eq. 1]

Other workers on maize have used similar values of the coefficient in Eq. 1 for example 0.73 (MCKEE 1964, DWYER & STEWART 1986) and 0.72 (KEATING & WAFULA 1992). Equation 1 has been reassessed due to the changes in genotypes since 1911 (BIRCH et al. 1999).

The expansion and duration of green leaf area determines the fraction of incident radiation intercepted by the crop. Leaf blades also provide the main path for transpiration and carbon harvesting. Kernel set in cereals such as maize and wheat is associated with intercepted radiation around anthesis (ANDRADE et al. 2000, OTEGUI & ANDRADE 2000). This relationship is being used to improve the prediction of kernel numbers (LIZASO et al. 2001). It is argued that maximum rates of photosynthesis are usually found in the top part of the canopy (WOODMAN 1971), therefore making it an advantage to have high leaf area proportions in the top portion of the canopy. However, the overall effect of the canopy architectures on growth and yield will also be modified by the overall canopy height, leaf shape and sizes (TAYLOR 1975). Dry matter accumulation is closely associated with leaf area development. The development of leaf area is a function of leaf numbers and leaf size these factors may change differently depending on the genetic material involved and the environment in which the plants are grown. Leaf number and leaf area development can help to elucidate plant dry matter production. Considerable variation in the amount and duration of green leaf area among genotypes has been reported (DWYER et al. 1992, ELINGS 2000). In ELINGS 2000, area of the largest leaf relative to total leaf area was said to be constant. This constant was found to be linear related to total leaf number. The relationship helps directly to estimate total leaf area, when total leaf number and the area of the largest leaf are known. In a modified form this method can be applied over a wide range of enviromental conditions. Some authors studying a limited number of genotypes suggested that variations in leaf area development could be forecasted adequately using generalised equations whose parameters are defined as a function of total leaf number (KEATING & WAFULA 1992, HAMMER et al. 1998). DWYER et al. (1992) showed that cultivars with the same number of leaves could have very different patterns of leaf area development. These are due to genetic differences. EL-SHARKAWY et al. (1965) suggested that the 100-fold difference in dry matter production per plant between sunflower (*Helianthus annuus L.*) and cotton was associated with the rate of leaf area development. IBRAHIM & BUXTON (1981) obtained similar results with okra leaf vs. normal leaf cottons. In several studies differences in total leaf area were associated with changes in leaf size rather than differences in total leaf number. In MCMICHAEL et al. 1984, leaf area was directly correlated with dry matter production, development of and increase in leaf area was strain-specific and depended on either increased leaf numbers or increased leaf size. Leaf expansion rate varies with leaf temperature, photon flux density (PPFD), evaporative demand and soil water status. Genotypic differences were observed by MADDONNI & OTEGUI 1996 in the leaf area of individual leaves maximum green leaf area index, green leaf area index above the ear, leaf angle and the progress of green leaf area index with time. These differences were reflected in fIPAR/ green leaf area index relationship.

Leaf area and light distribution are important input parameters in photosynthesis. The amount (leaf number) and distribution of leaf area are major factors determining light interception by plant canopy, which in turn, is essential in determining crop growth and yield (NORMAN 1978, GOUDRIAAN 1986). Leaf dimensions show some variation across environments and cultivars. Substantial differences in leaf production exist among cultivars from different regions (BIRCH & VAN DER PUTTEN 2003). Predicting plant leaf area production can be studied using a framework based on radiation intercepted radiation use efficiency (RUE) and leaf area ratio (LAFARGE & HAMMER 2002).

2.3 Leaf area index

The ratio of leaf surface to soil surface was termed leaf area index (LAI) by WATSON (1947). The LAI is defined as the projected leaf surface area per unit ground surface. However, recently LAI has been defined as one-half the total green leaf area per unit ground area (CHEN & CIHLAR 1996, CHEN et al. 1997). Estimates based on these two definitions can differ by a factor between 1.28 and 2.00 depending on the form of the object that is being described. The change in definition is related to the fact that optical instruments respond to half the total area of foliage elements rather than to the projected area. LAI = 0 means that no leaves or needles exist, LAI = 1 indicates that the leaf area equals the horizontal ground surface, LAI = 2 means that the leaf area is double the size as the ground surface area etc. In maize under conditions of optimal growth peak LAI ranged from 4.8 to 7.8 (LINDQUIST et al. 2005).

Leaf area index quantifies the amount of foliage per unit ground surface area. It is one of the "driving" biophysical variables and is therefore an important input parameter to many models, e.g. hydrological, ecological and climate models. LAI varies with plant/tree species as well as with mean annual temperature, length of the vegetation period, water supply (WULDER 1998) and stock age (SPANNER et al. 1994). LAI also influences the photosynthesis as well as the amount of perspired water and both of absorbed CO_2 and emitted O_2 through the leaf surface area. It is therefore an important steering parameter of the plant water balance and of the energy and mass exchange between vegetation and atmosphere (SPANNER et al. 1990, WULDER 1998). Growth and duration of green leaf area index of a crop determines the percentage of the incident solar radiation that will be intercepted by the crop canopy across time, thereby influencing canopy photosynthesis, photosynthate translocation and final yield (DALE et al. 1980).

Accurate measurements of LAI are laborious and time-consuming. Many methods of measuring LAI of corn *(Zea mays L.)* have been reported and vary greatly in their accuracy, precision, bias and ease of measurement. LAI can be quantified using direct or indirect field methods. A choice of any method used to measure leaf area depends largely on morphological features of leaves to be measured, accuracy required, amount of material to be measured and amount of time and equipment available (DAUGHTRY & HOLLINGER 1984). Several methodologies have been used for measuring LAI in the field. These can be classified in four categories:

- Direct measurements by litterfall collection or destructive sampling
- Allometric correlations with variables such as tree height or tree diameter
- Gap-fraction assessment (e.g. with hemispherical photographs)
- Measurements of light transmission with optical sensors

Optical instruments measure light transmittance beneath/within a canopy, i. e. gap fraction over a range of zenith angles is measured and gives the effective LAI (CHEN et al. 1997). The assumption for optical measurements is random distribution of foliage. This implies that LAI can be derived from the probability that a beam of direct radiation will pass unobstructed through a canopy. Light attenuation by successive leaf layers is related to LAI and is approximated by the Beer-Lambert Law (Eq. 2): where I is the irradiance at the ground level and Io is the irradiance above the canopy. The extinction coefficient k is related partly to the optical properties of the leaves and mainly to the structural properties of the canopy (height, stem density, leaf clustering and inclination etc.). It also depends on the radiation waveband that is considered. Simultaneous measures of I and Io yield a practical measurement of the LAI, provided that either an estimation of k or an adequate description of the foliage geometry is provided.

$$I = Io^{-kLAI} \qquad \text{[Eq. 2]}$$

Extinction properties and geometrical structure of the canopy are calculated from simultaneous measurements of light transmission under five different angles measured by five annular detectors, normalized to incident light values taken in the open.

2.4 Plant canopy analyser LAI 2000

This is a fast indirect method of measuring leaf area index (compared to the manual method) and other plant canopy structure attributes such as Mean Tip Angle (MTA). Measurements can be made under a variety of sky conditions and in canopies ranging in size from short grasses to forests. The LAI-2000 calculates LAI and other attributes from radiation measurements made with a “fish-eye” optical sensor - 148° field-of-view (DEBLONDE & PENNER 1994, LI-COR 1992). Measurements made above and below the canopy are used to determine canopy light interception at five angles, from which LAI is computed using a model of radioactive transfer in vegetative canopies. Measurements made by positioning the optical sensor and pressing a button, data are automatically logged into the control unit for storage and LAI calculations. After collecting above-canopy and below-canopy measurements the control unit performs all calculations and the results are available for immediate on-site inspection. The LAI-2000 calculations include: Leaf area index (LAI), mean foliage inclination angle and the fraction of the sky visible from beneath the canopy. LAI calculations using this method assume that the below-canopy readings do not include radiation that was reflected or transmitted by foliage, the foliage elements are small compared to the area of view of each ring. Since the optical sensor has a broad field-of-view the size of the canopy or plot is an important consideration. If the plot is too small the sensor's field-of-view will extend beyond the edge of the foliage being measured and LAI will be underestimated (or overestimated, if the plot is surrounded by denser foliage), the distribution of foliage elements are random the foliage is azimuthly randomly orientated, that is, it does not matter how the foliage is inclined, but the leaves should be facing all compass directions (DAUGHTRY & HOLLINGER 1984).

2.5 Specific leaf area

Specific leaf area is the ratio of fresh foliage surface area to unit dry foliage mass or projected leaf area per dry mass. GOWER et al. (1999) suggest its definition as half the total needle surface area referred to as hemisurface area. It has become an important variable in comparative plant ecology because it is associated with many critical aspects of plant growth and survival (SHIPLEY & VU 2002). SLA is often positively correlated with seedling potential relative growth rate (MULLER & GARNER 1990, POORTER & REMKES 1990) and leaf net photosynthetic rate (FIELD & MOONEY 1986, REICH et al. 1997, SHIPLEY & LECHOWICZ 2000), it is negatively correlated with leaf life span (REICH et al. 1992) and palatability to herbivores (LUCAS & PEREIRA 1990). SLA provides the coefficient to convert foliage mass to leaf area, that is, by multiplying the amount of carbohydrate available to leaves by specific leaf area (SLA). In other research work (TARDIEU et al. 1999, WILSON et al. 1999) SLA seems to suffer from a number of drawbacks. It is said to be very variable between the replicates and much influenced by leaf thickness. On the other hand, leaf expansion rate is considerably reduced by mild water deficits, which do not affect photosynthesis and is not affected by a reduction in the PPFD intercepted during rapid leaf expansion. SLA undergoes several - fold variability depending on the PPFD, soil water status and time of the day. It is increased when environmental conditions have a greater depressive effect on expansion rate than on photosynthesis and is decreased in the opposite case. It is reduced under drought conditions (MARCELIS et al. 1998). It is therefore appropriate to model leaf expansion independently of the plant carbon budget (TARDIEU et al. 1999). SLA is species dependent. It ranges in values from a lower limit of 12 to the upper limit of 40. Decrease in SLA in droughted plants may be due to the different sensitivity of photosynthesis and leaf area expansion to soil drying. Drought stress affects leaf expansion earlier than photosynthesis (TARDIEU et al. 1999). Reduction of SLA is assumed a way to improve water use efficiency (CRAUFURD et al. 1999). This is because thicker leaves usually have a higher density of chlorophyll and protein per unit leaf area and hence, have a greater photosynthetic capacity than thinner leaves. However there are interspecific variations in photosynthetic nitrogen-use efficiency (PNUE, the ratio of CO_2 assimilation rate to leaf organic content) in relation to SLA (POORTER & EVANS 1998). For plants grown under low irradiance, ambient PNUE of high SLA species was higher primarily due to their lower N content per unit leaf area. Low SLA species clearly had an overinvestment in photosynthetic N under these conditions.

2.6 Leaf angle

Interception of solar irradiation by leaf canopies is influenced by the canopy architecture of crops, which is a function of shape, distribution and orientation of the leaves that constitute the canopy (GIRARDIN & TOLLENAAR 1994). The amount and distribution of leaf area and leaf angles in a crop canopy determine how photosynthetically active radiation (PAR) is intercepted and consequently influences canopy photosynthesis and yield. Factors such as plant shape, plant populations and row width will affect these leaf distributions and can occur in an almost infinite number of different combinations. Depending on row widths plants with upright leaves can have both the smallest and the largest daily canopy photosynthesis (STEWART et al. 2003). Plants are able to modify their foliage architecture in response to the environment. In maize (*Zea mays L.*) for instance leaf orientation can switch from a random distribution in nearly isolated plants (i.e. 3 plants m^{-2}) to a ditch distribution where the leaves are placed perpendicular to rows, when the plants are grown at commercial crop densities. Orientation of leaves in a maize canopy is altered by intraspecific interference, thereby more effectively intercepting incident solar irradiance (STEWART & DWYER 1993, MADDONNI et al. 2001 a). Both field measurements and computer simulations indicate that maize canopies with leaves perpendicular to the rows may present increased light interception (about 10 % higher) and grain yield (about 10 % higher) than similar canopies with randomly orientated leaves. Across-row leaf orientation at high plant population should provide more rapid canopy closure, enhance crop competition with weeds and reduce dependence on herbicides while enhancing grain yield (TOLER et al. 1999, MADDONNI et al. 2001 b). This shade avoidance syndrome (SMITH 2000) involves a series of changes in plant architecture in response to the low red to far-red ratio of vegetation canopies, which improve the exposure of the foliage to photosynthetic light. Phytochrome–mediated changes include enhanced axis growth reduced branching, organ reorientation and accelerated flowering. Upright leaf angle has been proposed to increase canopy photosynthesis in situations where LAI already tends to be high, such as with high planting densities and narrow row spacings (LOOMIS & WILLIAMS 1969, DUNCAN 1971). Evidence indicating how leaf inclination angle influences canopy photosynthesis was reported with rice by TANAKA (1972). He demonstrated by mechanically manipulating the leaf arrangement, that a horizontal-leafed canopy showed a plateau type response of photosynthetic rate to radiation, with low photosynthesis, while an erect-leafed rice canopy showed a higher photosynthetic rate. The rice yield of the horizontal-leafed rice canopy was about 70 % that of the vertical-leafed rice canopy. The relative importance of these responses depends on the species. In maize plant stature and tillering responded to low red to far-red ratio but the largest effects were those associated with a redirection of the leaves toward gaps with high red to far-red ratio.

ROBERTSON 1994 in field studies indicated that vertical distribution of maize leaf area could be predicted in crop growth models from leaf appearance, final leaf number and additional information of leaf sizes and leaf angles. Across all genotypes, a consistent relationship was found between plant height increase and leaf appearance, with height increasing at a slow rate until the appearance of leaf 7, afterwards height increased at 5 times the initial rate until the appearance of the flag leaf. MADAKADZE et al. (1998) working with switchgrass populations showed that vertical distribution of LAI among populations differed throughout the growing season and that early in the seasons, the increases in light interception closely followed increases in LAI.

2.7 Leaf senescence

A normal process in the life cycle of plants is senescence. It is a terminal phase in the development of every organ, including leaves, stems, flowers and fruits. Senescence generally occurs without simultaneous growth, following organ maturity. It is influenced by environmental or endogenous (e.g. hormonal) perturbations by initiating or accelerating the different steps of the process. During this process in leaf a large part of leaf nitrogen, carbon and minerals is recycled to other organs of the plant (NOODEN 1988 a). In summer crops, such as sunflower, maize and sorghum, senescence starts before all the leaf area is fully developed (i.e. before flowering) and progresses at an increased rate during the grain-filling period. Consequently green leaf area duration has always been shown to depend on the availability of assimilates to sustain grain growth during the post-flowering period. There are two important factors regulating leaf senescence at the whole-plant level: source-sink-relationships and nitrogen (N) status in the plant (CHRISTENSEN et al. 1981, TOLLENNAAR & DAYNARD 1982, CRAFTS-BRANDNER et al. 1984, FELLER & FISCHER 1994). Changes in the source-sink-ratio during grain filling is frequently accompanied by a dramatic change in stover weight as the supply of assimilate by the sources and the demand of assimilate by the sinks is buffered by assimilates temporarily stored in the stover. Dry matter of stover has been found to either increase when assimilate supply exceeds demand for grain growth or decrease when the demand is greater than the supply from current photosynthesis (TOLLENNAAR & DAYNARD 1982, BARNETT & PEARCE 1983). Nitrogen (N) status also affects leaf senescence. Grain N is supplied from vegetative tissue as well as from concurrent N uptake (PAN et al. 1986). Nitrogen uptake is dependent upon availability of soluble carbohydrates to the roots (TOLLEY-HENRY et al. 1988) and consequently the critical period for N supply is during reproductive growth when partitioning of carbohydrates is shifted from support of root activity to support of ear growth. Reduction of N uptake will enhance N mobilisation from leaves and stems. N mobilisation from leaves brings a decline in photosynthetic activity and eventually leaf senescence (WADA et al. 1993). Acceleration of leaf senescence is also thought to be adaptive in plants subjected to water shortage because it reduces the water demand cumulated over the whole plant cycle, thereby avoiding water deficit during seed filling. It also allows recycling of scarce resources to the reproductive sinks. However, early leaf senescence in crop species correlates with lower yield because cumulative photosynthesis is reduced (WOLFE et al. 1988 a, b).

Selection based on delayed leaf senescence (stay-green plants) under drought conditions allowed obtaining sorghum hybrids with improved yields under water deficit (BORRELL et al. 2000 a, b). RAJCAN & TOLLENAAR (1999 a, b) attributed greater dry matter accumulation in some maize varieties tested to greater leaf longevity and that the number of green leaves, an indicator of leaf longevity, was greatest when supply and demand of assimilates during grain filling were approximately equal. The report also suggests that new hybrid had increased leaf longevity relative to an old hybrid, because of a larger source-sink-ratio during grain filling. According to VALENTINUZ & TOLLENAAR (2004), grain yield improvement of maize (*Zea mays L.*) hybrids has been associated with delayed leaf senescence. A top-bottom profile of leaf senescence was observed during the second half of the grain filling period with leaves in the central section of the canopy being the last leaves to senesce and this phenomenon was more marked in the newer hybrids. Nevertheless, stay-green plants do not necessarily produce higher yields, especially when chlorophyll catabolism and nutrient remobilization are disabled (THOMAS & HORWARTH 2000). Senescence is sped up by water or nitrogen deficits (WOLFE et al. 1988 a, b) and delayed when reproductive sinks are removed (NOODEN 1988 b, WOLFE et al. 1988 a). Prediction and manipulation of leaf senescence is therefore crucial to optimise crop management and plant response to water deficit.

2.8 Stay-green

Stay-green or delayed foliar senescence in maize is a secondary trait that divides maize varieties into two major maturity types. Delaying leaf senescence is an effective strategy for increasing cereal production, particularly under water-limited conditions (MAHALAKSHMI & BIDINGER 2002). A number of annual cereals exhibit genetic variation for the degree or rate of leaf senescence during grain filling (THOMAS & SMART 1993). Specifically, stay-green has been associated with reduced lodging, lower susceptibility to charcoal rot (MUGHOGHO & PANDE 1984) and improved grain filling and grain yield under stress (ROSENOW & CLARK 1981). Because of the benefits, selection for enhanced stay-green has been an important component of breeding for improved drought tolerance and improved grain yield in breeding programms in the USA (ROSENOW et al. 1983) and Australia (HENZELL et al. 1992) for many years. Although the ability of leaves to delay senescence has a genetic base in sorghum (VAN OOSTEROM et al. 1996), the expression of the character is strongly influenced by environmental factors. Sufficient expression of the trait for selection is thus dependent upon the occurance of a prolonged period of drought stress during the grain filling period, of sufficient severity to accelerate normal leaf senescence, but not of sufficient magnitude to cause premature death of the plants. In maize during the process of maturity there are varieties whose residual organs (leaves/stem) mature faster than the corn. While in another type, residual parts of the plant (leaves and stem) stay green longer than the cob rapidly matures (stay-green type). For silage purposes, the former types are suitable, while the latter are suitable for corn. Stay-green varieties have the advantage of maintaining healthy leaves and stem often times resistant to Helminthosporium and stemfusarium (EDER & WIDENBAUER 2003). The longer the leaves/stem stay green, than the corn matures, the more dry matter content begins to deteriorate. Varieties with stay-green trait tend to maintain more photosynthetically active leaves than varieties not possessing this trait, especially at postanthesis drought (ROSENOW et al. 1983). Expression of stay-green has been reported in *Sorghum bicolor (L.)*, *Zea mays L.* (RAJCAN & TOLLENNAAR 1999 a, b) as well as in other cereals like rice and oats.

Green leaf area at physiological maturity has proved to be an excellent indicator of stay-green and has successfully been used to select drought-resistant sorghums in the USA (ROSENOW et al. 1983) and in Australia (HENZELL et al. 1992). Key components, which determine green leaf area at maturity include: maximum green leaf area (total plant leaf area), duration of leaf senescence and rate of leaf senescence. Maximum green leaf area is the basis from which green leaf area at maturity is determined. It is from this point that the leaf area begins to decline according to the onset and rate of senescence up to maturity

Green leaf area at maturity can then be mathematically described as follows:

$GLAM = MGLA - (Duration_{sen} * Rate_{sen})$ [Eq. 3]

GLAM is green leaf area at maturity (cm² $plant^{-1}$), MGLA is the total plant leaf area (cm² $plant^{-1}$), $Duration_{sen}$ is the duration of leaf senescence (°C d) and $Rate_{sen}$ is the rate of leaf senescence (cm² $plant^{-1}$ °C d).

Therefore, once the maximum (total) plant leaf area is set, retention of green leaf area during grain filling will be determined by the time at which leaves begin to die (onset of senescence) and the rate at which death occurs (rate of senescence) [BORRELL et al. 2000 a].

Two factors that affect the components of green leaf area at maturity are water and genotype (variety). Timing and severity of drought are critical in determining both leaf area development and subsequent senescence. To improve yield under drought knowledge of the extent of genotypic variation in the components of green leaf area at maturity is required, especially higher total plant leaf area, delayed onset of leaf senescence and reduced rate of leaf senescence are all pathways to increased green leaf area at maturity. Environmental conditions resulting in high leaf area production at anthesis followed by severe postanthesis water deficit are most conducive to the expression of stay-green (BORRELL et al. 2000 b). Genotypic differences in delayed onset and reduced rate of leaf senescence were explained by differences in specific leaf nitrogen and nitrogen uptake during grain filling. Leaf nitrogen concentration at anthesis was positively correlated with onset and negatively correlated with the rate of leaf senescence under terminal water deficit (BORRELL & HAMMER 2000).

2.9 Leaf (area) duration

Duration of leaf senescence is defined as the number of degree-days from the onset of senescence to physiological maturity. The importance of longer growth duration was amplified in the quest to increase the productivity of rice (*Oryza sativa L.*) up to 15 t ha^{-1} in irrigated ecosystems in Asia (KROPFF et al. 1994). High nitrogen use efficiency trait of OBA SUPER 2 (KLING et al. 1996, OIKEH et al. 1996) possibly resulting from longer green leaf area duration and it's direct impact on extending the period of dry matter accumulation after anthesis, translated to grain production.

2.10 Light interception

The accumulation of biomass by crops results from the amount of incident photosynthetically active radiation (PAR) intercepted by the canopy and from the efficiency with which the intercepted PAR is converted into dry matter. The terms intercepted radiation and absorbed radiation are often used interchangeably in literature, but distinction has been made between the two terms by ASRAR et al. (1989) and RUSSELL et al. (1989). Intercepted radiation does not explicitly consider radiation absorption. Although photons must be intercepted before they can be absorbed, some are scattered (reflected or transmitted). However, GALLO & DAUGHTRY (1986) observed that the differences between IPAR and APAR were less than 3.5 % from planting until just before physiological maturity of corn. Thus IPAR is a reasonable approximation of APAR as long as full green canopies are present. The difference between APAR and IPAR for incomplete canopies or canopies which include senesced plant material may be large.

Crop photosynthesis and hence bio mass production are directly associated with light interception by the canopy (MUCHOW et al. 1990). Light interception has been related to the leaf area index (LAI) of the crop by exponential functions (JONES & KINIRY 1986) of the general form:

$$fIPAR = a\ (1-e^{-kLAI}) \qquad [Eq. 4]$$

Where fIPAR is the fraction of photosynthetically active radiation intercepted by the canopy k is the attenuation coefficient and is a plateau value. Evidence exists of differences in light interception along the cycle in maize (LOOMIS et al. 1968) and in sorghum (ROSENTHAL et al. 1985). These differences may be partly explained by: i) senesced leaves, which continue to intercept light but are not included in the measurement of LAI (GALLO et al. 1993) and ii) light interception by the panicles (DUNCAN et al. 1967, TETIO-KAGHO & GARDNER 1988 a, b). In maize similar exponential functions for the relationship between fIPAR and green LAI (GLAI) have been found (JONES & KINIRY 1986, MUCHOW et al. 1990), but with differing values of the estimated attenuation coefficient (k) and of the maximum value of fIPAR (the plateau value a). Differences in both coefficients are probably due to effects of cultivar differences in plant height (EDMEADES & LAFITTE 1993), leaf angle (LOOMIS et al. 1968, PEPPER et al. 1977), leaf number and LAI (DWYER et al. 1992) on radiation interception with time. Sowing date (ANDRADE et al. 1993, CIRILO & ANDRADE 1994), plant population (LOOMIS et al. 1968) and water regime (MATTHEWS et al. 1988, MUCHOW 1989) may also modify canopy structure resulting in a particular pattern of fIPAR evolution. As light travels downwards through a canopy it suffers a reduction in its photosynthetic photon flux density and a significant alteration in its spectral composition. Because absorption by green tissues is more intense in the blue (400-500 nm) and red (600-700 nm) wavebands and reflection is more intense in the far-red waveband (700-800 nm). The red to far-red ratio reaching the plant base is greatly reduced at high leaf area indexes. Thus, the vertical profile of light quantity and quality within a canopy are known to regulate leaf senescence rate. MADDONNI & OTEGUI 1996 have observed genotypic differences in the area of individual leaves.

During the presilking period, dry matter distribution among leaves, stems and roots is simulated as a function of temperature and stage of development (TOLLENAAR 1989 a, b). If the daily assimilate demand by the grain exceeds the assimilate supply by net crop photosynthesis, remobilization of carbohydrates occurs from stems and leaves. The reduction in leaf weight can result in a reduced potential leaf photosynthetic rate and eventually leaf senescence. The self-destruction of a maize canopy due to low source-sink-ratio has been documented by TOLLENAAR & DAYNARD 1982). During the post silking period grain growth has priority for assimilate over vegetative tissue. Grain growth is the product of kernel number and rate of dry matter accumulation per kernel. Kernel growth is dependent only on temperature, if the assimilate is not limiting after the onset of the linear period of grain filling (TOLLENAAR & BRUULSEMA 1988). Differences in yield potential among species appear in part to be associated with differences in effective filling period. Genetic variability for filling period exists among genotypes of maize (DAYNARD et al. 1971, DAYNARD & KANNENBERG 1976).

2.11 Radiation use efficiency

Variability within a crop species in the amount of dry mass produced per unit intercepted solar radiation or radiation use efficiency (RUE) is important for the quantification of plant productivity. RUE is easily measured in field experiments and is used to quantify plant growth. It is used to integrate leaf area, solar radiation interception and productivity per unit leaf area into crop productivity. Differences in dry matter accumulation among crop cultivars can be attributed to differences in either the absorption of incident photosynthetically active radiation (PAR) and/or the conversion of absorbed PAR into dry matter (TOLLENAAR & AGUILERA 1992). Linearity has been found between CO_2 assimilation of canopies integrated over one day (daily assimilation) and daily absorbed or intercepted PAR, implying constant photosynthetic RUE on a daily basis (SINCLAIR & MUCHOW 1999). Increased dry matter accumulation of new maize hybrids after silking can be attributed, in a large part, to increased radiation use efficiency. Drought stress reduces the efficiency with which absorbed PAR is used by the crop to produce new dry matter (the radiation use efficiency RUE) [EARL & DAVIS 2003]. This can be detected as a decrease in the amount of crop dry matter accumulated per unit of PAR absorbed over a given period of time (STONE et al. 2001) or as a reduction in the instantaneous whole-canopy net CO_2 exchange rate per unit absorbed PAR (JONES et al. 1986). Slow development of maize (*Zea mays L.*) canopies may limit light interception and potential productivity (WESTGATE et al. 1997). Early canopy closure through narrower row spacings and greater plant population densities than normally used for hybrids adapted to particular location may increase RUE and grain yield. MUCHOW & DAVIS (1988) related RUE to specific leaf N (SLN) (0.5-1.6 g N m^{-2} of leaf) for sorghum and maize. There are numerous reports of lower RUE after silking (MUCHOW & SINCLAIR 1994, MAJOR et al. 1991).

2.12 Temperature sum (GDD, HU)

Temperature among environmental factors is considered the primary determinant of plant development rate. A system to quantify the rate as a function of temperature was introduced more than two centuaries ago (WANG 1960) and is in use today for various crops, although not necessarily in the same form as originally proposed. The relation of accumulated thermal units to crop development has been variously tested (CROSS & ZUBER 1972, BUNTING 1976), compared between crops (NEILD 1982). In general the effect of temperature on plant functioning is brought about by the action on enzymatic activities. A large number of enzymes play a role in plant development and presumably enzymes providing photosynthesis are very important. There is a great deal of difference between C-3 and C-4 species as far as enzymes involved in photosynthesis are concerned. The pyruvate-phosphate dikinase, which provides the phosphoenolpyruvate (PEP) and hence CO_2 acceptor in C-4 species, is sensitive to low temperature (EDWARDS & KU 1987). Whereas the Rubisco found in the C-3 species is very efficient even at low temperatures. This difference is clearly expressed in the leaf development temperature response. The ‘degree-day’ unit stems mainly from the relationship between development rate and temperature. The same grains are harvested in very different climates it would be interesting to compare the sums of heat degrees over the months during which wheat does most of its growing and reaches complete maturity in hot countries like Spain and Africa or in temperate countries like France and in the colder countries of the North.

Growing degree-days (GDD) or Heat Units (HU) is frequently used to describe the timing of biological processes (McMaster & Wilhelm 1997). The basic equation used is eq. 6. Two methods of interpreting this equation for calculating GDD are: method 1 if the daily mean temperature is less than the base, it is set equal to the base temperature or method 2 if T_{max} or $T_{min} < T_b$, they are reset equal to T_b. Differences between the methods occur if Tmin is less than Tb and then method 1 accumulates fewer GDD than method 2) (McMaster & Wilhelm 1997). When incorporating an upper threshold as commonly done with corn, there was a greater difference between the two methods.

In practice, the concept of growing degree-days (GDD) assumes that plant growth is related directly to the average daily temperature. The degree-days for each day are added together or accumulated throughout the growing season. If mean daily temperature is equal or less than the base temperature, the degree-days value is zero (Edey 1977).

In Europe through the widespread temperature sum of AGPM (L'Association Générale des Producteurs de Maïs) developed in France between 1978 and 1983 similar in principle to GDD (Growing-Degree-Days in the US) and CHU (Corn Heat Unit in Canada), growth and maturity stages in maize crop can be estimated (Eder & Krützfeldt 2000, Herrmann 2000, Pickert et al. 2001, Rath et al. 2002). Low temperature and drought may limit potential leaf expansion, which in effect affects photosynthesis and hence crop yield. Temperature can influence crop yields through effects on radiation interception, radiation use, yield component elaboration and/or carbohydrate partitioning. Lafitte & Edmeades (1997) indicated that adaptation groups differed greatly in grain and total biomass production across enviroments, large differences were observed in harvest index, supporting the hypothesis that temperature has important effects on dry matter partitioning to grain, all yield components were affected. Muchow 1990 showed that the rate of grain-growth increased and the duration of grain-filling was shorter as temperature increased and that whilst the rate of both milk-line and black-layer development increased with temperature the development of milk-line was less variable and proved to be the better indicator of the end of effective grain-filling. Maize cultivars with broad thermal adaptation may be useful in areas where the crop experiences large fluctuations in temperatures or when a cultivar is targeted for several areas with contrasting temperature regimes. However, it may not be possible to select a cultivar with high and stable grain yield across temperatures ranging from 13 °C to 28 °C, because cool and warm temperature adaptation may be mutually exclusive traits. Broad adaptation is possible across a more moderate range of temperatures, however and can be improved by selection

(LAFITTE et al. 1997). The duration of development period in maize (silage) is influenced above all by temperature conditions (SCHUPPENIES 1989). The sum of an effective temperature is a measuring number, with which the period is defined and the course of maturity stated. The estimation of the course of maturity through temperature sum requires determination of dates of development stages.

2.13 BBCH Decimal Codes for the growth stages of maize

Virtually all growth processes in plants such as leaf photosynthesis and dry matter distribution are influenced by stages of development and duration of the same, which affects crop dry matter accumulation and grain yield. In crop production crops with identical phenological growth stages are grouped under a general form of decimal scale known as BBCH-Code (WEBER & BLEIHOLDER 1990). For instance the BBCH-Codes for the growth stages of maize, rape, field beans, sunflower and peas allows the use of identical code numbers for similar phenological growth stages of the different plant species, although it cannot describe special features of each crop or weed in detail. Owing to its universal usability BBCH-code has greatly contributed in the standardization and rationalization in Agricultural research work (BLEIHOLDER et al. 1990). The extended BBCH scale is a system for coding of phenologically similar growth stages of all mono- and dicotyledonous plant species based on the well known cereal code of ZADOKS et al. 1974 and HACK et al. 1992. The BBCH key is a decimal system with 10 principal growth stages and up to 10 secondary ones starting with seed germination and sprouting of perennials progressing through leaf production and extension growth to flowering and senescence. Therefore, it can also be a suitable tool to define the growth stages of different weed species (HESS et al. 1997).

Phenology, photosynthesis and partitioning are the three most important components of the maize-crop-growth simulator (MAIS). The phenological phase duration (planting to silking, silking to maturity) increases or decreases proportionally to the change in duration of the entire life cycle expressed in thermal leaf units (BOOTE & TOLLENAAR 1994). The course of growth and development of maize plant during the vegetation period is the foundation for yield formation (GEISLER 1983). Accurate simulation of phenology is important because dry matter accumulation and grain yield are directly related to the duration of the life cycle and virtually all growth processes (leaf photosynthesis, dry matter distribution) are a function of stage of development. TOLLENAAR et al. (1979) simulated mais phenology using the relationship between temperature and rate of leaf appearance, genetic and environmental influences on duration of the life cycle expressed as effects on total leaf number (TOLLENAAR

& HUNTER 1983). Although no new leaves emerge after silking the relationship between rate of leaf appearance and temperature (thermal leaf units) is assumed to quantify the rate of development during the entire life cycle of maize.

2.14 Forage quality and NIRS

The quality control of agricultural products is an important field of interest in agricultural research and advisory work (VOLKERS et al. 2003). Evaluation of hybrid stability for yield and forage quality is therefore an important criterion in forage production. Plant cells can be divided into cell solubles and cell wall material. Cell solubles are contained within the boundaries of the cell wall and are easily digested. Cell solubles include crude protein (nucleic acids, amino acids, proteins and other nitrogen-containing compounds), sugars, starch and lipids (fats). In comparison the cell wall contains slowly digestible material called fibre, which includes hemi-cellulose, cellulose and the mostly indigestible substance lignin. These fibre fractions are included in the neutral detergent fibre (NDF) and acid detergent fibre (ADF) fractions often used in forage analysis reports. Decline in cell solubles are due to increased fibre (cellulose, hemi cellulose and lignin) movement of nutrients from leaves to roots and leaching of cell solubles by rain and snow during dormancy. Near infrared reflectance spectroscopy (NIRS) provides a method for the simultaneous measurement of multiple quality traits like in vitro digestible organic matter (IVDOM), crude protein (XP), crude starch, insoluble organic substances (IOS), crude fibre (XF), acid detergent fibre (ADF), sugar content and dry matter content. Dry matter content of cob is an essential characteristic used in estimation and assessment of nutrient content and energy concentration of silage maize (KNABE et al. 1987). A rise in dry matter content in cob is accompanied by decrease in crude fibre content. A rise in starch content is accompanied by increase in energy concentration in the whole plant. A major advantage of near-infrared reflectance spectroscopy (NIRS) is its ability to analyse samples without chemical treatments, hence costs sample material (BARBER et al. 1990) and chemical wastes can be reduced. Furthermore, NIRS has less variance in analyses of the same sample than laboratory analyses (MARUM & AASTVEIT 1990). The use of NIRS to predict the quality of forage maize at a mature stage is commonly accepted (MAINKA 1990, PAUL et al. 1992). Although the feeding value of maize silage is considered as rather constant (COX et al. 1994), its digestibility and energy content may vary due to growth conditions and genotype (DEINUM & STRUIK 1988). Particularly under less favourable climatic conditions in the northern parts of Europe, where a low temperature sum during the growing season, (or on the reverse, in areas of high temperature and heat) regularly restricts the growth of maize, its quality can vary considerably. Thus, an accurate prediction of the quality is essential to meet the animals' requirements and to avoid nutrient losses to the environment (VOLKERS et al. 2003). Sample handling, processing and analysis methods are important in NIRS analysis. A high level of accuracy and precision in the laboratory will not improve upon poor sampling technique, nor will it give more accurate analysis for estimating composition (NIRS 2 Version 3.0 1992).

Forage value of silage maize depends very strongly on the degree of maturity of the maize plant at the time of silage. Various experiments have documented the best time to harvest corn for silage to optimize yield and quality (BAL et al. 1997, WEAVER et al. 1978). WIERSMA et al. (1993) reported that corn silage quality is inversely related to the stage of maturity at harvest. With the development of a prognosis model, it is now possible to estimate the optimum time for harvest, that is, the point of increased (maximum) forage value with reduced losses and fixing of appropriate dates of labour requirement. However, it is uncertain to estimate the maturity time due to changing weather conditions (RATH et al. 2002). The most important parameters (characteristics) of forage ration besides mineral substances are energy content, crude protein, starch and sugar contents, are forage structures which include crude fibre, ADF and NDF. Crude ashes are another determinant of the energy content of silage. This is because it does not contribute in supply of energy, but rather acts as a thinning (diluting) factor. It also contains dirts or pollutants in form of sand. Therefore, correct determination of crude ashes is a basic forage analysis requirement (TILLMANN 2002). Forage value of maize is basically defined through the concurrent developmental processes of cob and residual plant during the generative development (DEGENHARDT 1996). In this phase transfer of nutrients from stem, leaves and cob leaf to the cob occurs (HEPTING 1988). This results in a continuous increase in the portion of energy-rich cob in whole plant-dry mass. According to HEPTING (1988) this process depends strongly on genotype and environmental conditions.

3 Material and Methods

3.1 Field research station Berge - location, soil and weather conditions

Berge research station, belonging to the Institute of Crop Science, Faculty of Agriculture and Horticulture (Humboldt-University) is located in Brandenburg area, about 40 km north-west of Berlin. It lies towards the north, west and south rolling Nauener plane on a geographical latitude of 52°37'N, longitude of 12°47'E and altitude NN 40 m. Soil type is Orthic Luvisols, gray brown podzolic soils. Soil texture is loamy sand to sandy loam (top), sand to sandy loam (below). Table 1 shows soil texture and table 2 chemical composition upto 50 cm of soil depth.

Table 1: Soil texture at Berge research station (KÖHN 2002)

Depth [cm]	Coarse Sand	Medium Sand	Fine Sand	Coarse Schluff	Medium Schluff	Fine Schluff	Clay
0-20	**4.1**	**30.1**	**41.4**	**8.4**	**4.7**	**3.5**	**7.8**
30-50	**3.8**	**28.7**	**41.6**	**8.8**	**4.5**	**3.8**	**8.8**

Table 2: Soil chemical composition at Berge research station (KÖHN 2002)

Depth [cm]	Organic matter	P	K	Mg	Cu	Mn	Zn	pH
	%	**mg 100 g^{-1} soil**			**ppm**			
0-20	**1.4**	**22.9**	**14.5**	**6.3**	**4.8**	**78.0**	**5.8**	**6.1**
30-50	**1.3**	**19.2**	**20.4**	**9.0**	**4.1**	**52.3**	**4.8**	**6.8**

Rainfall and air temperature means recorded over a period of 30 years (between 1971 and 2000) are indicated in table 3. The mean air temperature for the years from 1971 to 2000 was 9.3 °C, while the rainfall mean over the same period of time was 502 mm.

Table 3: Temperature and rainfall means between 1971 and 2000, Berge (KÖHN 2002)

Month	Mean daily temperature [°C]	Rainfall [mm]	Month	Mean daily temperature [°C]	Rainfall [mm]
January	**0.7**	**35.0**	**July**	**18.6**	**46.8**
February	**1.1**	**28.5**	**August**	**18.2**	**54.1**
March	**4.3**	**35.9**	**September**	**13.9**	**41.3**
April	**8.3**	**30.9**	**October**	**9.3**	**31.9**
May	**13.8**	**47.5**	**November**	**4.4**	**37.2**
June	**16.7**	**65.6**	**December**	**1.8**	**47.2**

Daily weather focus was monitored from the meteorological station located within the experimental field [temperature (°C), rainfall (mm) and other parameters]. Mean monthly air temperature and rainfall distribution for each experimental year of 2002 and 2003 were calculated.

Climatic conditions of the research station over the period between 1971 and 2000 were also compiled (in this experiment only mean monthly temperatures and rainfall were considered).

In year 2002 over 737 mm precipitation was recorded at the Research station of Berge, out of which 325 mm fell within the vegetation period. The average temperature within the same period was 17.6 °C. Year 2003 was characterised by low rainfall figures (342 mm), nearly half that of 2002. Approximately half of annual precipitation for each year was received during the vegetation period.

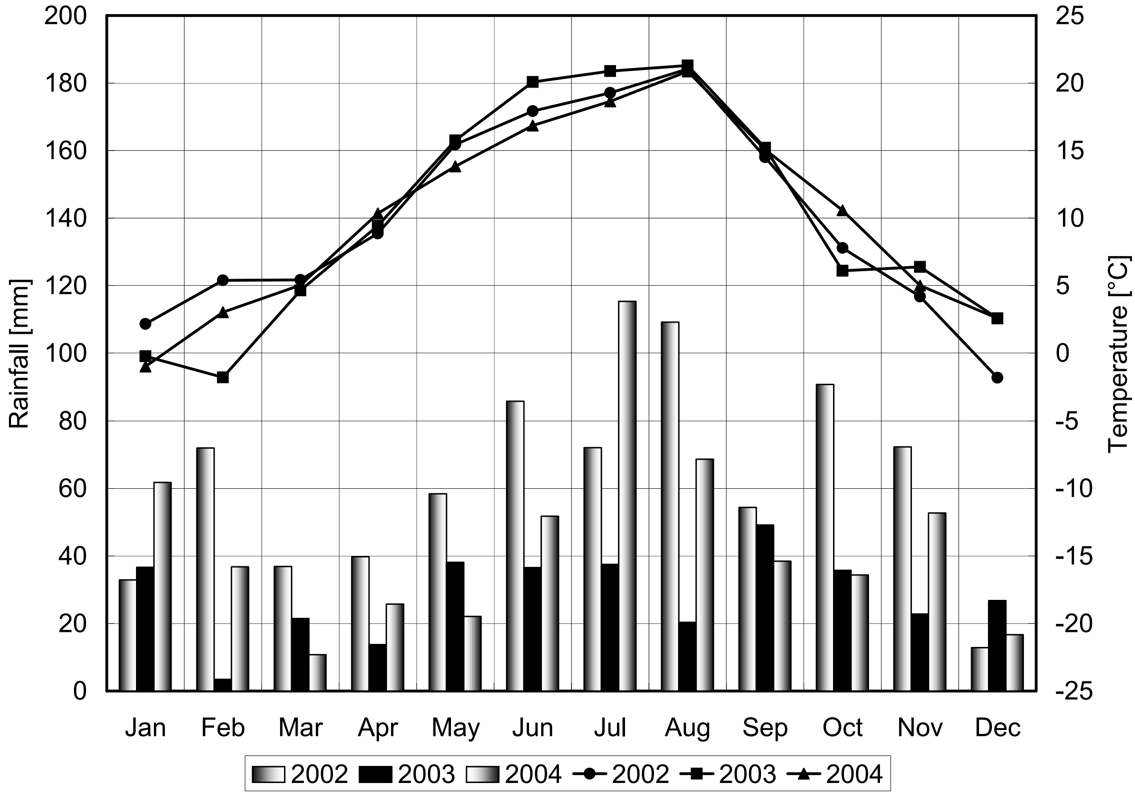


Figure 1: Mean monthly rainfall distribution (mm) and air temperature for experimental years 2002, 2003 and 2004

The figure 1 shows precipitation (mm) and corresponding mean air temperatures during the experimental years 2002 and 2003. As indicated comparing to the long-term averages, the year 2002 received the highest rainfall during the vegetation period. Rainfall over a period of 30 years (1971-2000) at the experimental site averaged 501.9 mm during 12 months and nearly 250 mm during the growing period from May to September. In the experimental year 2003, a severe water shortage was noted in the month of August which led to an earlier than usual harvest of the crops, especially of early varieties whose leaves dried out faster than those of mid-early maturity varieties. Long-term averages for air temperatures during the vegetation period were lower than in 2002 and 2003. Again highest mean air temperatures during the vegetation period were recorded in 2003, with the highest mean air temperature in the month of August (21.3 °C). However, there was no considerable deviation from long-term average temperatures in both experimental years 2002 and 2003.

3.2 Silage maize maturity groups used

All the silage maize varieties used in the experimental years 2002, 2003 and 2004 including selected and recommended varieties fall under maturity groups as follows:

Early maturity group: S 180 - S 220

Mid-early maturity group: S 230 – S 250

Mid-late maturity group: S 260 – S 280.

A difference of 10 in silage maturity number signifies a one percent point difference in dry matter content of the whole plant. Classification of maize genotypes by maturity group according to FAO number does not consider the differences in full maturity of rest of the plant. That results in yearly re-classification of some individual genotypes from one group to another (WANG 2001).

Table 4: Early and mid-early silage maize varieties at location Berge (check and core varieties 2002-2004)

Year	Early maturity group		Mid-early maturity group	
	Number (varieties)	**Check varieties**	**Number (varieties)**	**Check varieties**
2002	**20**	**Tassilo Symphony Diplomat Sagitta**	**22**	**Probat, Fjord Romario, Eurostar Effekt, Rivaldo**
2003	**18**	**Pernel, Tassilo, Symphony, Ravenna Talman, Early Star Ambros, PR39G12 PR39P49**	**25**	**LG 3226, Rivaldo Sandrina Acapulco Topper Flavi**
2004	**16**	**Tassilo Baxxos Nescio**	**25**	**Rivaldo, LG 3226 Topper, Lacta PR39B50, Pontos**
Core varieties	**3**	**Tassilo Baxxos Nescio**	**6**	**Lacta, LG 3226 Pontos, R39B50 Rivaldo, Topper**

3.3 Measurements and observations

Leaf area and leaf area index measurements were done once in a week throughout the vegetation periods. Leaf area index was obtained through manual measurements and the use of a LAI 2000 plant canopy analyser instrument. With the LAI 2000 other parameters like light interception and leaf mean tilt angle were also obtained. Both methods were deployed on the same dates of measurements, but not started on the same dates. Manual measurements were started on earlier stage of leaf development than LAI 2000 in both years. Plant height was also measured on the same dates including other observations like leaf number, total number of senesced leaves, number of nodes per plant, number of cobs per plant and cob leaf positions, mechanical damages by wind or heavy rain and infections by insects and pests. Intermediate harvest was conducted in 2002 to determine leaf area and leaf area index by the integration method. The results obtained were used in 2003 for varieties, which were tested in both years.

During the measurements of leaves (length and breadth), every leaf was labelled using a water resistant marker beginning with the lowest, marked 1, up to the top last fully expanded leaf. Only leaf lengths of the remaining, non-fully expanded leaves were measured. The next date of measurements proceeded with the previous, non-fully expanded leaves. This facilitated faster measurements as unnecessary repetitions of the already fully expanded leaves during previous measurements were avoided. The assumption made was that the leaves, which were considered fully expanded, increased no more in length or width after the last date of measurement. In 2003 only leaf lengths were measured, while in the previous year both leaf length and width were measured simultaneously in every date of measurement until full expansion. The results of leaf measurements of 2002 of the same varieties tested in both years were applied in 2003 in intergration to find the leaf factors of the same varieties.

Maturity groups of early and mid-early varieties of forage maize were used (tables A1-A5). The genotypes were planted as sub-plots in a randomised complete block design with four replications (Figure A1-A4). Planting was done on 30.04.2002 and 29.04.2003. Each plot consisted of 4 rows, 10 metres long and 3 metres wide.

Measurements, numbering, observations and data collections made during the vegetation period included:

- Measurement of plant height (cm)
- Number of nodes
- Leaf area of individual leaves (length * breath)* factor
- Number of cobs per plant

- Location of the cob-leaf on the plant

- Number of withered (dead) leaves per plant: counting of dry (withered) leaves was done on every date of measurements starting from the first leaf generation, moving upwards. Leaf senescence from the top downwards was also noted as the plants approached maturity. Rates of individual leaf senescence were also approximated through visual observations as a fraction of the green part of the leaf (3/4, 1/2, 1/3 and 1/4).

- Total number of leaves per plant (leaf generation): was considered the number of leaves from the first leaf that appeared after germination to the last top most leaf of the plant.

- Breakage

- Insect infections

- Measurement of LAI with the Plant Canopy Analyser LAI 2000: This instrument measured and computed a combination of parameters including leaf area index (LAI), leaf angle and light interception.

- Two methods were used to determine leaf area and leaf area index of the varieties.

3.3.1 Manual method of measuring LA and LAI

Using a meter stick, the length and breadth of each leaf of the tagged plants were measured from the first leaf generation upwards. Leaf length was considered as the length from a leaf base to leaf tip, leaf breadth as the breadth of the widest portion of the leaf blade (cm). Further measurements were stopped after the leaf had attained full expansion indicated by the exposure of the leaf base. The leaf area of every individual leaf was determined by multiplying length and breadth and a factor of a given leaf.

Leaf area was determined using the formula:

$$LA = \text{length} * \text{breadth} * \text{factor } b1 \quad \text{[Eq. 5].}$$

Factor b1 is a coefficient depending on the individual leaf and its development (according to KVET et al. 1971, HATFIELD et al.1976). Factor b1 lies between 0.65 and 0.80. In year 2002 and partly in 2003, specified plants in the inner row of each plot were harvested in mid July (the time when maximum leaf areas for all the varieties were attained). All existing green leaves were removed from the stock arranged on tables in ascending order from the lowest leaf to the last (in order of leaf generation). Beginning with the lowest leaf each leaf was folded into 1/2, 1/4 and 1/8 segments (a total of 5 segments per leaf were obtained). Widths of these segments were measured, including width of leaf base. The full length of each leaf was measured. Using integration method, the leaf factor was calculated for individual leaf generation. With the three parameters: leaf length, leaf width and leaf factor known, leaf area of each individual leaf was calculated as a product of the three parameters. Leaf factor results of the varieties tested in 2002 were used in the calculation of leaf area of these same varieties, which were tested in 2003. The procedure of finding leaf factor was repeated only on the newly introduced varieties in 2003. This was also partly due to the time consuming labour intensive nature of the procedure. The leaf area index of every plot was the product of the sum of all individual leaves of a plant and the plant density divided by the total area occupied by the plants.

3.3.2 Plant canopy analyser LAI 2000 method of measuring LAI

Using LAI-2000 five measurements were made, within the row adjacent to the marked plant. The first measurement was taken above the plant canopy the other four were taken below the plant canopy diagonally across the rows. The first one was taken in the row, the second ¼ of the way a cross, the third in the middle and the fourth ¾ of the way across the row. Measurements were taken in the early morning hours of the day (8°° - 11°°) to avoid the effect of direct sun- rays and also under obscured cloudy conditions, whereby the contribution of scattered radiation is low. Some measurements were also done in the late evening hours on clear days (from 16°° until 18°°), where direct sunrays or drizzles. View caps were used to block undesired objects from the sensors view, such as the operator, a neighbouring plot and portion of the sky, which contains the sun. Under critical conditions of intermittent rainfall or open sky, direct sun-ray, which could affect the results, only two replications per maturity group were measured. However this method was not used simultaneously at the start of manual measurement (was used from 23.07.02, when most of the plant leaves were already fully opened and from 18.06.03). LAI calculations using this method assume that the below-canopy readings do not include radiation that was reflected or transmitted by foliage, the foliage elements are small compared to the area of view of each ring. Since the optical sensor has a broad field-of-view, the size of the canopy or plot is an important consideration. If the plot is too small, the sensor's field-of-view will extend beyond the edge of the foliage being measured and LAI will be underestimated (or overestimated, if the plot is surrounded by denser foliage), the distribution of foliage elements is random, the foliage is azimuthly randomly orientated, that is, it does not matter how the foliage is inclined, but the leaves should be facing all compass directions (DAUGHTRY & HOLLINGER 1984).

3.4 Growing Degree Days (GDD)

Using the formula according to AGPM (L'Association Générale des Producteurs de Maïs):

$$GDD = \sum_{T1}^{T2} \left[\left(T\max + T\min \right) / 2 - Tb \right] \qquad \text{[Eq. 6]}$$

Whereby:

T1: sowing to flowering

T2: Flowering to silage maturity

T_{max}: maximum daily temperature

T_{min}: minimum daily temperature

T_b: base temperature (8°C)

When $[(T_{max} + T_{min})/ 2] < 8$, that day was not counted (ignored) and when $T_{max} > 30$, Tmax was taken as 30, temperature sum were calculated for the entire vegetative period. Through this method, dates and particular phases of development with their corresponding temperature sum could be found.

3.5 Data analysis

Analysis of variance and evaluation of the 10-years research series were carried out using EFDAS 1 and 2 Programme (Bundessortenamt 1993a, b). Forage quality was analysed using Near-Infrared Reflectance Spectroscopy (NIRS) method carried out at the Regional department for consumer protection and agriculture at Paulinenaue. Analysis were conducted for both years and pooled together. F values for treatment effects and their interactions were considered significant at the $P < 0.05$. However due to various reactions of the trials and different environmental conditions (soil and weather), any significant effect on the trials (variety) can be interpreted for each year separately (BÄTZ 1984). Yield and quality analysis of silage maize was done through separate harvesting of cob (including cobleaf) and residual plant components (stems and leaves) from the inner rows of the plots. From the probes dry matter contents were calculated.

NIRS analysis of forage quality: Whole plant probes were taken to the department of grassland and fodder production, consumer protection and agriculture. Starch content, crude protein, crude fibre as well as contents of enzyme-soluble organic substances were analysed. Out of these results, energy content was estimated using the estimation formula according to WEIßBACH et al. (1996 a, b).

4 Results

4.1 GDD at germination, silking and harvest periods in 2002 – 2004

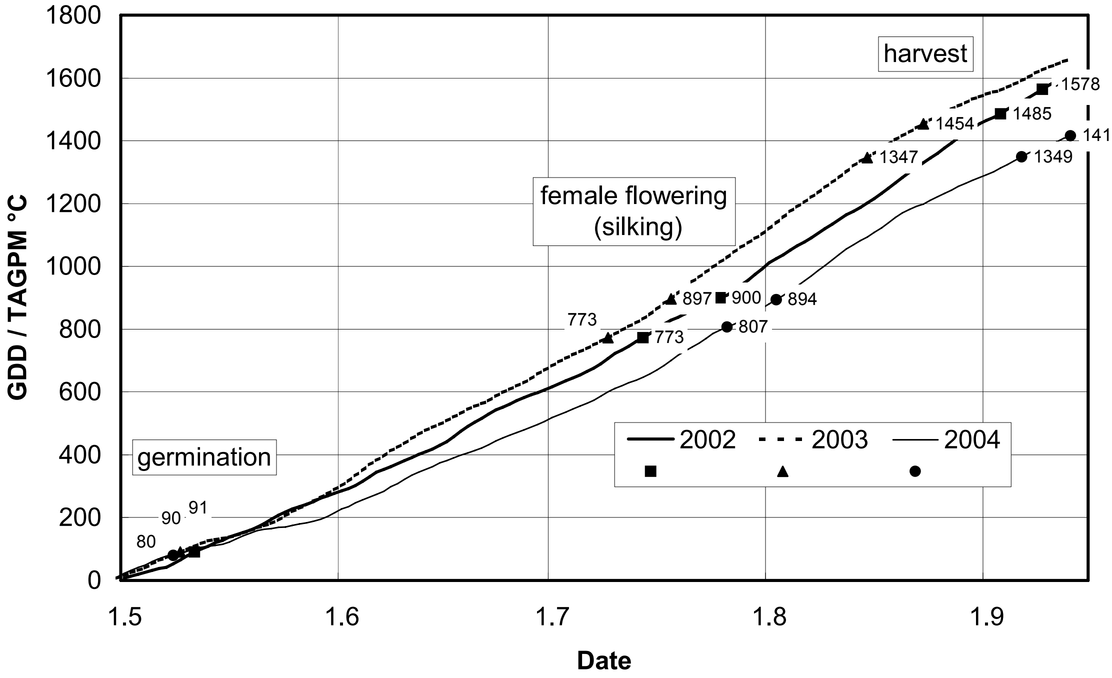


Figure 2: Temperature sums (GDD) during the four successive years 2002 - 2004 growing seasons of forage maize at location Berge

Figure 2 shows ranges of temperature sums (according to AGPM, L'Association Générale des Producteurs de Maïs) at three points of the vegetation period (germination, silking and harvest) over a period of three successive years, 2002-2004. According to AGPM developed in France, the base minimum temperature is considered to be 6°C.

4.2 Leaf area and leaf area index (Manual measurement)

The results of leaf area index and leaf area development in early and mid-early maturity groups during the vegetation periods are shown in figures 3 and 4. Only core varieties of the maturity groups are represented in the figures. Year 2004 results were incorporated here for the purpose of comparing the results for the three successive years, though it was not originally part of this experiment.

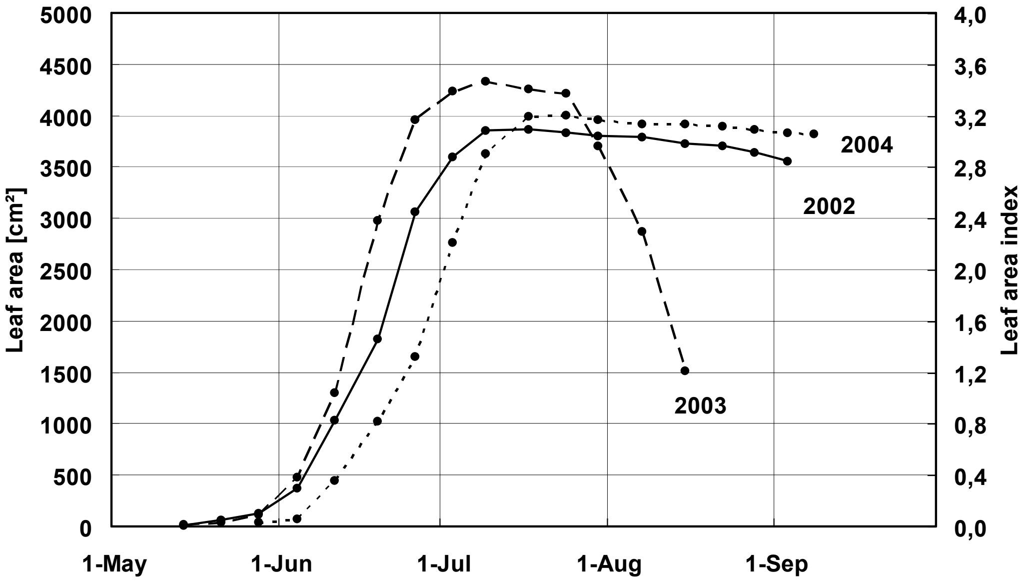


Figure 3: Whole plant green leaf area and leaf area index (average of core varieties Baxxos, Nescio, Tassilo, Arsenal and Symphony)

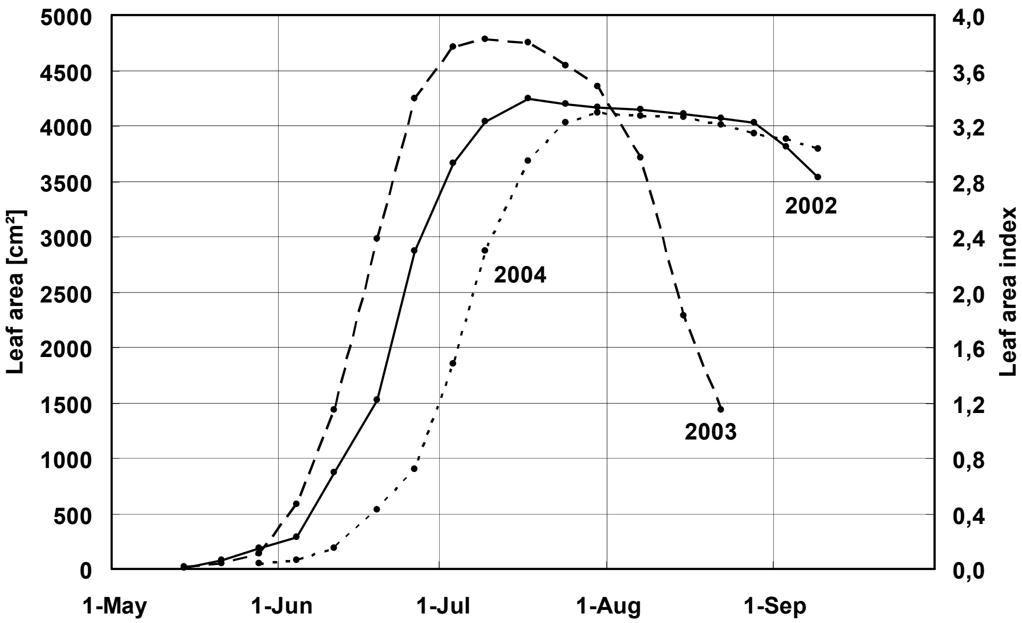


Figure 4: Whole plant green leaf area and leaf area index (average of core varieties: Lacta, LG3226, Pontos, PR39B50, Rivaldo and Topper)

Figures 5 and 6 show the overall view of maximum leaf area index of each variety within the maturity groups in year 2002. Not included here, were the selected and recommended silage maize varieties for Brandenburg region in year 2002, which included early, mid-early, mid-late varieties and variety FAO 750. Leaf area index for both maturity group fall between 3-4, with mid-early maturity group tending to higher LAI than early group.

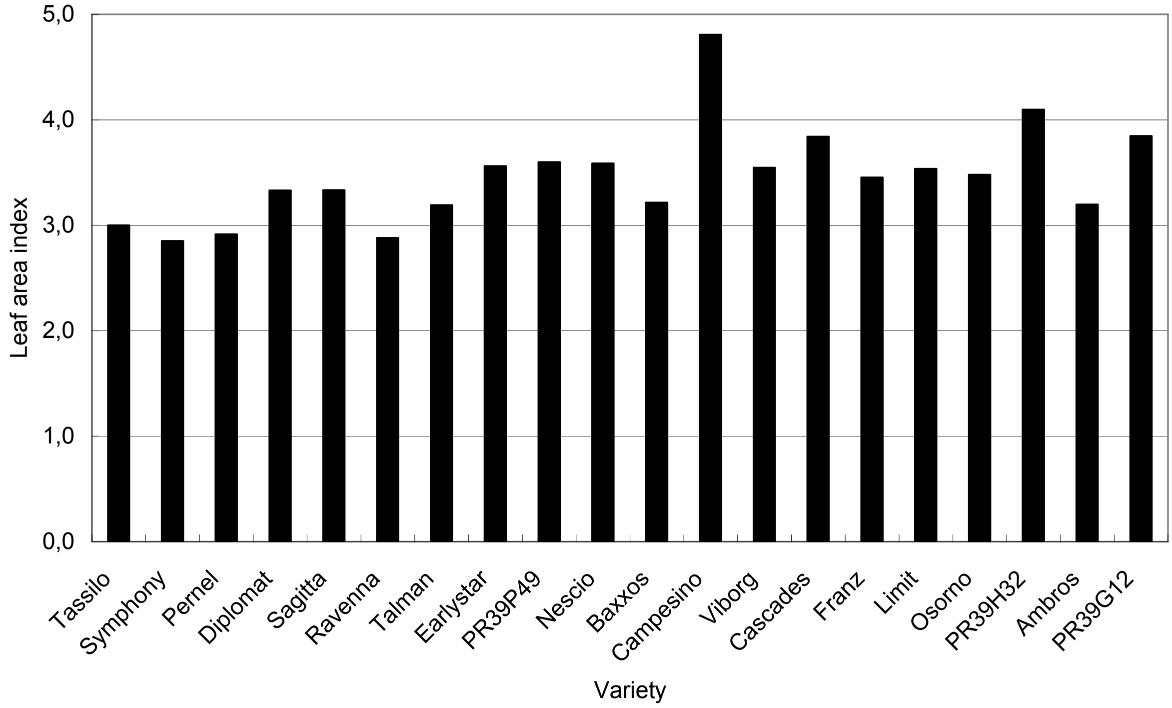


Figure 5: Leaf area index (max.) of early maturity varieties by manual measurement in 2002

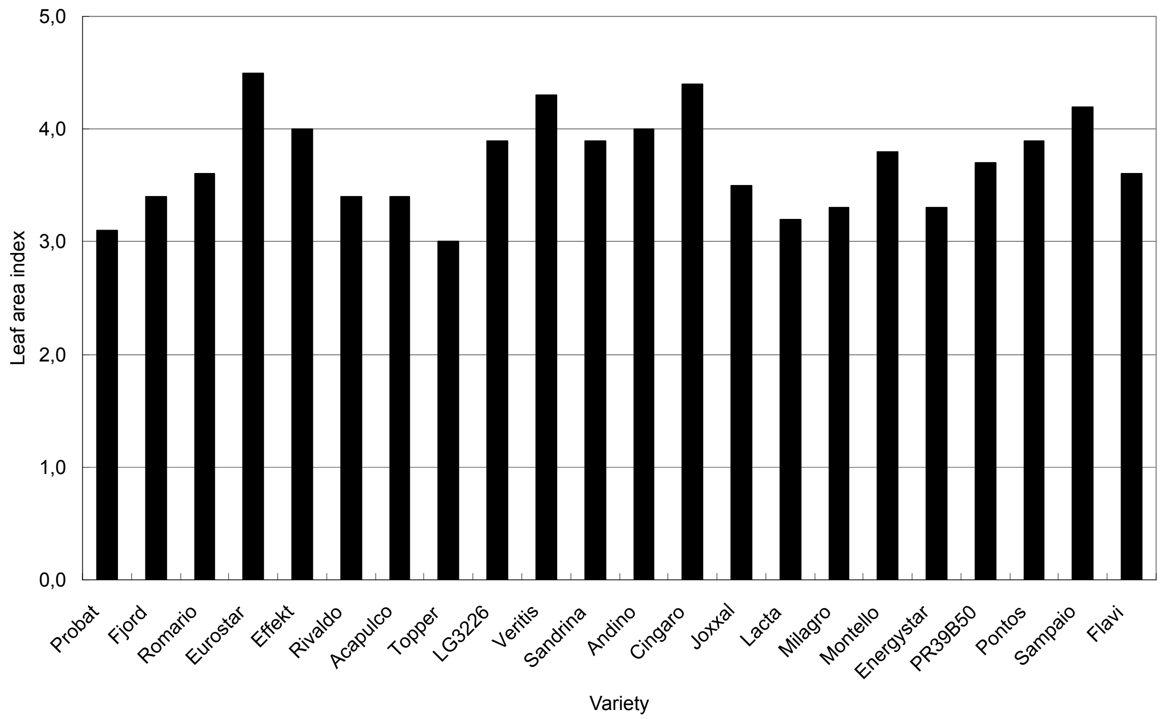


Figure 6: Leaf area index (max.) of mid-early maturity varieties by manual measurement in 2002

Table 5: Leaf parameters of reference plants of silage maize, early and mid-early maturity groups in regional variety trial of Brandenburg in the year 2002 at location Berge (Harvest: 03.09. and 09.09.2002 respectively)

Variety	Maturity number	Maximum leaf area [cm²]	Maximum LAI	Green leaf area at harvest [cm²]	LAI at harvest	SLA of all leaves at harvest [cm²g⁻¹ DM]
			Early			
X Tassilo	**S 200**	**3630**	**2.90**	**3307**	**2.65**	**151**
X Symphony	**S 220**	**3504**	**2.80**	**3232**	**2.59**	**149**
X Diplomat	**S 210**	**4034**	**3.23**	**3796**	**3.04**	**154**
X Sagitta	**S 210**	**3902**	**3.12**	**3574**	**2.86**	**150**
X Average (n=4)		**3767**	**3.01**	**3477**	**2.78**	**151**
LSD (α=5 %)		**665**	**0.53**	**679**	**0.54**	**16**
			Mid-early			
X Probat	**S 230**	**3928**	**3.14**	**3618**	**2.89**	**131**
X Fjord	**S 240**	**3847**	**3.08**	**3115**	**2.49**	**164**
X Romario	**ca. S 240**	**4422**	**3.54**	**4009**	**3.21**	**154**
X Eurostar	**ca. S 240**	**5730**	**4.58**	**5180**	**4.14**	**159**
X Effekt	**S 240**	**4685**	**3.75**	**4327**	**3.46**	**153**
X Rivaldo	**S 240**	**4280**	**3.42**	**3697**	**2.96**	**154**
X Average (n=6)		**4482**	**3.59**	**3991**	**3.19**	**152**
LSD (α=5 %)		**552**	**0.44**	**666**	**0.53**	**19**

X Check variety

Leaf parameters were obtained from reference plants during the 2002 and 2003 vegetation periods (table 5 and 6). Intermediate harvest was done at the period of silking to determine maximum leaf area and leaf area index. The difference between maximum leaf area at flowering and green leaf area at harvest indicates the amount of green leaf area lost to senescence, which also expresses the intensity of the same. Specific leaf area was also calculated from all leaves measured at harvest, but the first five lower leaf generations that dried and withered out were not included in the measurements for SLA. Only check varieties of the maturity groups in years 2002 and 2003 are included in the tables.

4.3 Leaf area index measurement using LAI 2000 plant canopy analyser

Leaf area measurements in 2002 using LAI 2000 plant canopy analyser were started in the third week of July (table 7) earlier developments in leaf area index could therefore not be presented by this method. Only check varieties of the maturity groups are presented in the tables. This was also the period when most varieties were approaching the phase of maximum leaf area. Results of LAI by LAI 2000 for all the varieties, tested in each maturity group in both years, are shown in Appendix 10, 11, 12, 13 and 14.

Table 6: Leaf parameters of reference plants of silage maize, early and mid-early maturity groups in regional variety trial of Brandenburg at location Berge (Harvest: 15.08. and 23.08.2003 respectively)

Variety	Maturity number	Maximum leaf area [cm²]	Maximum LAI	Green leaf area at harvest [cm²]	LAI at harvest	SLA of all leaves at harvest [cm^2g^{-1} DM]
			Early			
X Pernel	**S 190**	**4341**	**3.47**	**1460**	**1.17**	**208**
X Tassilo	**S 200**	**4086**	**3.27**	**2129**	**1.70**	**182**
X Symphony	**S 220**	**4408**	**3.53**	**1320**	**1.06**	**195**
X Ravenna	**S 210**	**4191**	**3.35**	**1320**	**1.06**	**181**
X Talman	**S 210**	**4411**	**3.53**	**1030**	**0.82**	**185**
X Early Star	**S 220**	**4665**	**3.73**	**1444**	**1.16**	**199**
X Ambros	**S 220**	**4550**	**3.64**	**1389**	**1.11**	**195**
X PR39G12	**ca.S 220**	**5012**	**4.01**	**2297**	**1.84**	**197**
X PR39P49	**S 220**	**4242**	**3.39**	**1427**	**1.14**	**175**
X average	**(n = 9)**	**4434**	**3.55**	**1535**	**1.23**	**191**
LSD (α=5 %)		**411**	**0.33**	**680**	**0.54**	**18**
			Mid-early			
X LG 3226	**S 240**	**4483**	**3.59**	**1523**	**1.22**	**182**
X Rivaldo	**S 240**	**4795**	**3.84**	**1286**	**1.03**	**183**
X Sandrina	**S 250**	**4989**	**3.99**	**804**	**0.64**	**176**
X Acapulco	**S 230**	**4299**	**3.44**	**867**	**0.69**	**187**
X Topper	**S 230**	**4862**	**3.89**	**1187**	**0.95**	**186**
X Flavi	**S 250**	**4439**	**3.55**	**1301**	**1.04**	**163**
X Average	**(n = 6)**	**4644**	**3.72**	**1161**	**0.93**	**179**
LSD (α = 0.05)		**790**	**0.63**	**1065**	**0.85**	**23**

X Check variety

In 2003 measurements with LAI 2000 were taken at an earlier stage of leaf development than in 2002 (table 8). The last measurement for mid-early maturity group was done when early varieties were already harvested.

From table 9 for mid-early check varieties it is observed that the leaf area index of all the varieties had already considerably expanded by the first measurement (18th June), using LAI 2000 plant canopy analyser. Proceeding measurements showed increase in leaf area index, up to a peak level between 15th July and 24th July. Later measurements indicated a decline in leaf area index up to the time of harvest. A sharp LAI decline corresponded to the period of water deficit between 08th August up to the time of harvest and high temperature, which caused leaf wilting at the beginning and drying of leaves with time. The average maximum leaf area index was 3.57 on the 24th July LAI measurements, although some individual varieties had already attained maximum LAI before this time. Comparison between such varieties that attained maximum LAI earlier than the others and dry matter yield, dry matter content and starch yield, to check if there could be any additional advantage over other varieties with slower rate of LAI attainment could be appropriate.

Table 7: Leaf area index of early and mid-early check varieties of forage maize using LAI 2000 in year 2002 at location Berge

Variety	Date			
	22.07.	**31.07.**	**07.08.**	**15.08.**
Early				
X Tassilo	**2.82**	**2.90**	**3.16**	**3.10**
X Symphony	**3.53**	**3.73**	**3.91**	**3.95**
X Diplomat	**3.13**	**3.22**	**3.40**	**3.51**
X Sagitta	**2.54**	**3.53**	**3.67**	**3.70**
X Average	**3.26**	**3.35**	**3.53**	**3.57**
LSD (α =5 %)	**0.28**	**0.27**	**0.30**	**0.32**
Mid-early				
X Probat	**3.03**	**3.19**	**3.12**	**3.17**
X Fjord	**3.32**	**3.41**	**3.46**	**3.57**
X Romario	**3.12**	**3.32**	**3.31**	**3.49**
X Eurostar	**3.37**	**3.54**	**3.39**	**3.67**
X Effekt	**3.39**	**3.62**	**3.51**	**3.59**
X Rivaldo	**3.15**	**3.32**	**3.22**	**3.34**
X Average	**3.23**	**3.40**	**3.33**	**3.47**
LSD (α = 5 %)	**0.232**	**0.250**	**0.271**	**0.390**

Table 8: Leaf area index of early check varieties of forage maize using LAI 2000 in year 2003 at location Berge

Variety	Date								
	18.06.	25.06.	03.07.	08.07.	15.07.	24.07.	29.07.	8.08.	12.08.
X Pernel	**1.82**	**2.22**	**2.74**	**3.06**	**3.18**	**2.28**	**2.32**	**1.32**	**0.81**
X Tassilo	**1.55**	**2.03**	**2.56**	**2.90**	**2.67**	**2.13**	**2.18**	**1.28**	**0.71**
X Symphony	**1.92**	**2.48**	**2.92**	**3.05**	**3.11**	**2.53**	**2.41**	**1.49**	**0.89**
X Ravenna	**1.96**	**2.22**	**2.74**	**2.89**	**2.80**	**2.46**	**2.31**	**1.39**	**0.80**
X Talman	**1.67**	**2.16**	**2.83**	**2.75**	**2.88**	**2.54**	**2.31**	**1.24**	**0.62**
X Early Star	**1.68**	**2.07**	**2.52**	**2.99**	**2.96**	**2.35**	**2.21**	**1.33**	**0.90**
X Ambros	**1.66**	**2.13**	**2.47**	**2.88**	**2.82**	**2.57**	**2.54**	**1.40**	**0.78**
X PR39G12	**1.95**	**2.4**	**2.74**	**2.85**	**3.04**	**2.40**	**2.00**	**1.28**	**0.80**
X PR39P49	**1.99**	**2.34**	**2.69**	**2.93**	**3.11**	**2.56**	**2.34**	**1.28**	**0.91**
X Average	**1.80**	**2.23**	**2.69**	**2.92**	**2.95**	**2.42**	**2.29**	**1.33**	**0.80**
LSD (α = 0.05)	**0.21**	**0.17**	**0.22**	**0.24**	**0.45**	**0.43**	**0.24**	**0.16**	**0.31**

Early maturity varieties indicated LAI approaching a value of 2 at the first measurement of 18.06.2003 (table 8). The average values of LAI in early maturity varieties were on the lower than those of mid-early maturity varieties for every date of measurement. However, unlike mid-early maturity varieties, whereby maximum LAI were attained at later dates, between 15th and 24th July, early maturity varieties attained maximum LAI at earlier dates, between 3rd and 15th July. The average maximum LAI for early maturity varieties was 2.95 recorded on the 15th July measurement (compared to 3.57 for mid-early maturity varieties).

Table 9: Leaf area index of mid-early check varieties of forage maize in 2003 using LAI 2000 plant canopy analyser in year 2003, Berge

Variety	Date									
	18.06	25.06	03.07.	08.07.	15.07.	24.07.	29.07.	08.08.	12.08.	18.08.
X LG 3226	**1.76**	**2.40**	**2.86**	**3.17**	**3.35**	**3.67**	**2.83**	**1.91**	**0.95**	**0.87**
X Rivaldo	**1.80**	**2.39**	**3.01**	**3.14**	**3.39**	**3.52**	**2.85**	**2.23**	**1.48**	**1.27**
X Sandrina	**2.04**	**2.29**	**2.85**	**3.28**	**3.43**	**3.57**	**3.16**	**1.94**	**1.31**	**1.06**
X Acapulco	**1.83**	**2.38**	**2.83**	**2.92**	**3.26**	**3.59**	**2.77**	**2.03**	**1.25**	**1.02**
X Topper	**2.07**	**2.57**	**3.06**	**3.34**	**3.71**	**3.68**	**3.42**	**2.33**	**1.20**	**1.06**
X Flavi	**2.01**	**2.43**	**2.91**	**3.03**	**3.28**	**3.38**	**2.95**	**1.83**	**1.32**	**1.18**
X Average	**1.92**	**2.41**	**2.92**	**3.15**	**3.40**	**3.57**	**3.00**	**2.05**	**1.25**	**1.08**
LSD (α = 0.05)	**0.18**	**0.30**	**0.28**	**0.30**	**0.29**	**0.31**	**0.47**	**0.44**	**0.22**	**0.16**

A short characteristic of averages of check varieties (X), averages of all varieties in each maturity group (Average), coefficient of variation (CV %), least significant differences (LSD) and standard deviation (SD) from the results obtained through LAI 2000 plant canopy analyser (Table 10 and 11).

Table 10: LAI measurement with LAI 2000 plant canopy analyser of early and mid-early maturity group of forage maize in year 2002, Berge

Variety	specifications	23.07.02	31.07.02	07.08.02	15.08.02
Early	**X average (n = 4)**	**3.258**	**3.345**	**3.534**	**3.566**
	Average (n = 20)	**3.205**	**3.272**	**3.476**	**3.530**
	CV (%)	**6.076**	**5.896**	**6.109**	**6.383**
	LSD(α =0.05)	**0.276**	**0.273**	**0.301**	**0.319**
	SD	**0.097**	**0.096**	**0.106**	**0.113**
Mid-early	**X average (n = 6)**	**3.229**	**3.997**	**3.333**	**3.472**
	Average (n = 22)	**3.201**	**3.351**	**3.310**	**3.420**
	CV (%)	**5.137**	**5.280**	**5.796**	**8.071**
	LSD (α = 0.05)	**0.232**	**0.250**	**0.271**	**0.390**
	SD	**0.082**	**0.088**	**0.096**	**0.138**

Figure 7 indicates the results of the two methods used to determine leaf area index in early maturity group. Manual method was deployed from early stage of crop development, 14 days after sowing, while LAI 2000 was used at a later date (18.06) during the vegetation period. As the figure indicates, LAI by manual method had higher values than those of the counterpart LAI 2000.

Table 11: LAI measurements with LAI 2000 plant canopy analyser of early and mid-early maturity group of forage maize in year 2003, Berge

Variety	Specifi-cations	Date									
		18.06.	25.06.	03.07.	08.07.	15.07.	24.07.	29.07.	08.08.	12.08.	18.08.
Early	**n = 9(X)**	**1.80**	**2.23**	**2.69**	**2.92**	**2.95**	**2.42**	**2.29**	**1.33**	**0.80**	
	n = 18	**1.82**	**2.28**	**2.70**	**2.89**	**2.97**	**2.43**	**2.29**	**1.38**	**0.83**	
	CV (%)	**8.23**	**5.214**	**3.92**	**5.78**	**10.56**	**8.38**	**7.42**	**8.31**	**17.72**	
LSD (α = 0.05)		**0.21**	**0.17**	**0.22**	**0.24**	**0.44**	**0.43**	**0.24**	**0.16**	**0.31**	
Mid-	**n = 6(X)**	**1.92**	**2.41**	**2.92**	**3.15**	**3.40**	**3.57**	**3.00**	**2.05**	**1.25**	**1.08**
early	**n = 25**	**1.90**	**2.37**	**2.89**	**3.15**	**3.40**	**3.53**	**3.08**	**2.16**	**1.29**	**1.05**
	CV (%)	**6.53**	**9.10**	**6.90**	**6.77**	**5.97**	**6.23**	**10.74**	**14.27**	**12.24**	**11.10**
LSD (α = 0.05)		**0.18**	**0.30**	**0.28**	**0.30**	**0.29**	**0.31**	**0.47**	**0.44**	**0.22**	**0.16**

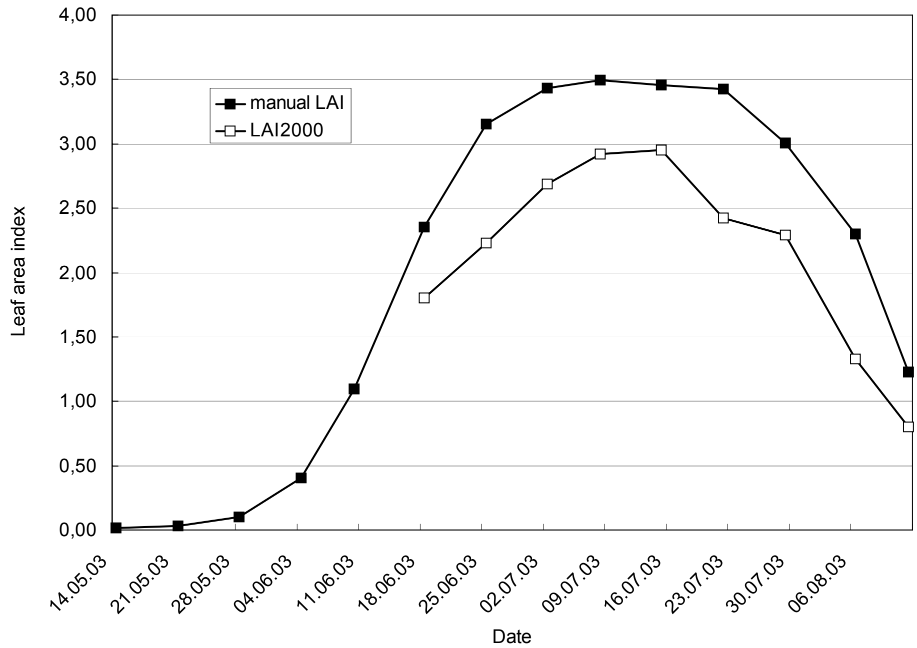


Figure 7: Leaf area index by manual and LAI 2000 plant canopy analyser measurements of early maturity check varieties in 2003, Berge

The results of LAI by manual and LAI 2000 methods are indicated in figure 7. Measurement of LAI by LAI 2000 was started at a later date (18.06) A drop in LAI curve of LAI 2000 measurements in 23.07 was a result of incomplete measurements of the replications due to bad weather (rain).

4.4 Light interception and leaf angle

The results of the experiment indicated close relationship between leaf area index, leaf angle and light interception. For the early maturity varieties leaf area index ranged between 2.0 and 2.4 (figure 9, year 2003), leaf angles were between 51° and 59° (average) and light interception between 70 and 83 %. Most of the intercepted light was however between 77 and 79 %, which corresponded to varieties with mean leaf angles lying between 55 and 57°.

The results also showed that certain varieties within this group with leaf angles between 51° and 55° attained maximum leaf area index above 2.3, while a majority of the varieties within this group had leaf angles ranging from 55 to 57°, but had lower leaf area index than the former between 2.1 and 2.3.

At a lower leaf area index was less light intercepted by the plants. This was manifested on both ends of the vegetation period. Firstly, at the beginning of the vegetation period leaf numbers were low consequently for some varieties, which also had lower leaf expansion rates than others their leaf areas were relatively small. An example of such varieties was Arsenal in early maturity group whose leaf area index increased slower than the rest of the check varieties within that group, which had also the lowest value of maximum leaf area index. However it maintained a longer period of maximum leaf area index than the rest of the check varieties except for variety Pedro. This characteristic could compensate for the low LAI by exposing the photosynthetic apparatus to a longer period for light interception and photosynthesis. A combination of these factors including a more horizontal leaf angles at this period of growth affected leaf area index and light interception. Most varieties of the early maturity group intercepted maximum light between 77 and 79 % and this was between the range of 2.1 and 2.3 of leaf area index. However, fewer varieties (4) attained higher LAI above 2.3 and maximum light interception above 80 %.

A reduction in leaf number and leaf area had occurred when leaf senescence set in. Photosynthetic active areas of the leaves were reduced during leaf senescence as the lower (older) leaves paled and dried off. Senescence started from topmost leaves proceeding downwards during the later stage of maturity. Senescence was less pronounced in 2002 than in 2003 among the groups due to a more favourable weather condition during the vegetation period. In 2003 water deficit in August quickened the leaf dry out. However, the phenomenon of drought could help to trace some important factors among the varieties like drought tolerance and the effects of water deficit on the so called stay-green varieties. Figure 8 shows the relationship between leaf area index and light interception by early maturity varieties of maize in 2002.

As the figure 8 indicates a majority of the varieties within this group intercepted maximum light between 90 – 95 % at corresponding LAI of 3.0 – 3.8. These values were higher than those of year 2003 in comparison, which were 75 – 83 % intercepted light at average LAI between 2.0 and 2.4 (figure 9).

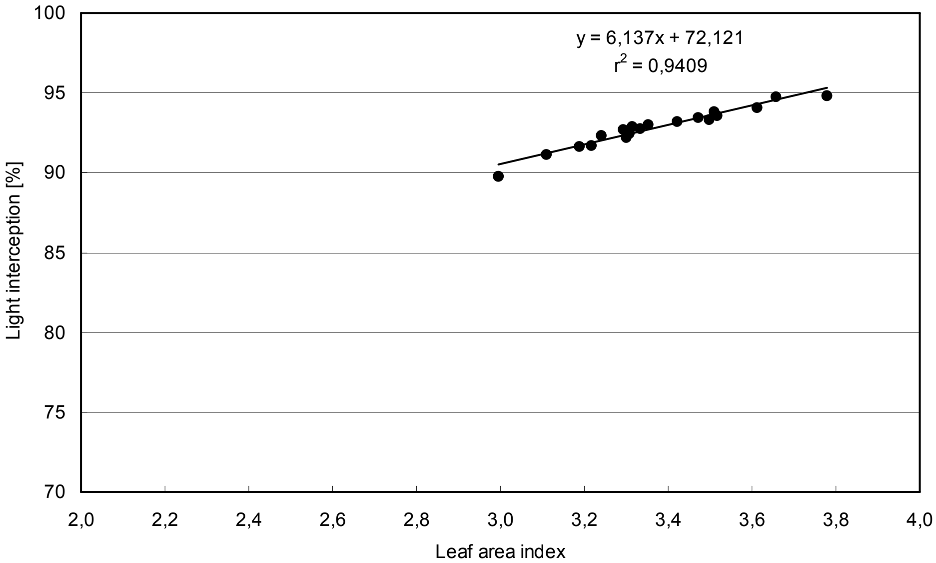


Figure 8: Leaf area index and light interception by early maturity varieties of forage maize in year 2002, Berge

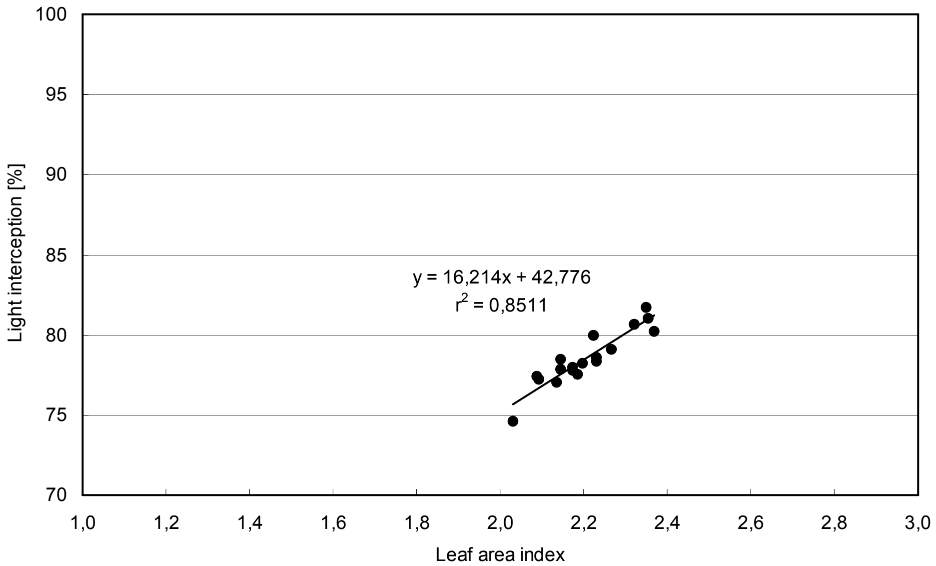


Figure 9: Leaf area index and light interception by early maturity varieties of forage maize in year 2003, Berge

Light interception within early maturity varieties was linear in relationship to leaf area index. Most of the light intercepted (between 75 and 83 %) fell within the leaf area index of 2.0 and 2.4. Compared to mid-early maturity group early maturity group had lower mean leaf area indices consequently much less light was intercepted by early maturity varieties than mid-early group. This affected the results of dry matter yield and energy yield, which were lower in early maturity group than in mid-early maturity group. However, similar trends in these parameters were also seen in year 2002 in that the values of the said parameters were lower in early than in mid-early maturity groups.

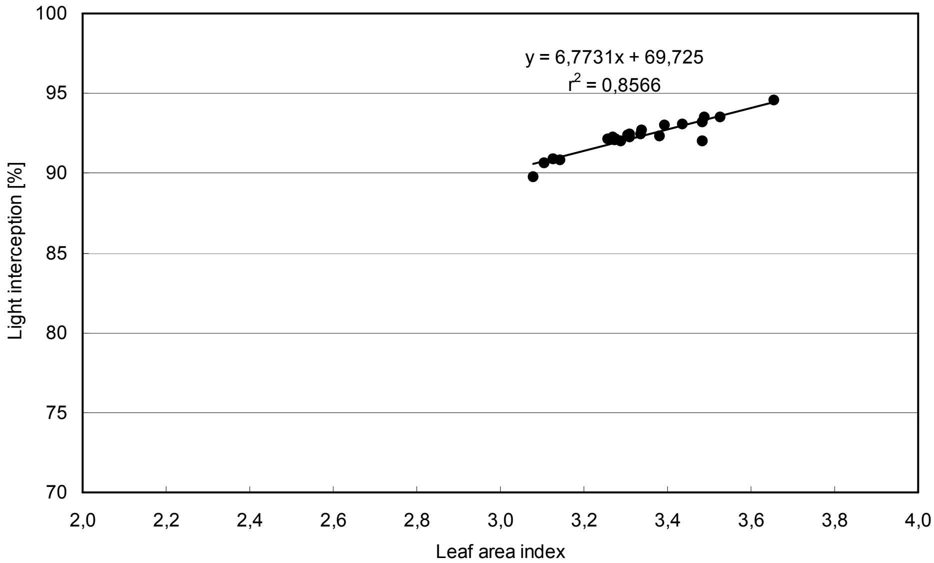


Figure 10: Leaf area index and light interception by mid-early maturity varieties of forage maize in year 2002, Berge

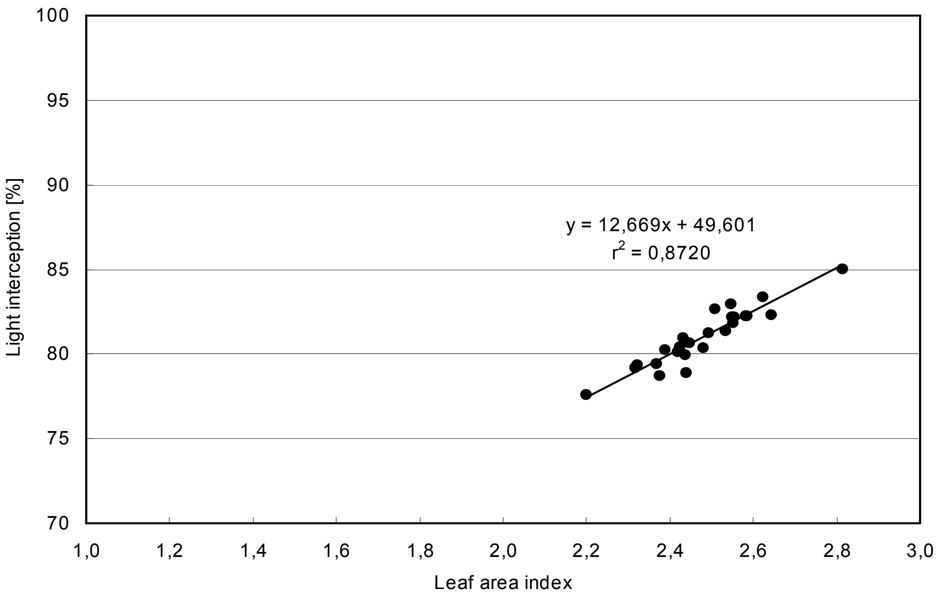


Figure 11: Leaf area index and light interception by mid-early maturity varieties of forage maize in year 2003, Berge

The figure 10 shows the relationship between LAI (mean) and intercepted light in by mid-early maturity varieties of forage maize in the year 2002. It indicates that maximum light of between 90 and 95 % was intercepted by most of the varieties within this group, this fell between LAI of 3.0 – 3.7.

The figure 11 of mid-early maturity varieties shows a close link between leaf area index and intercepted light. Greater light was intercepted by varieties with larger leaf area indices. Comparing with early maturity varieties (figure 10) there was more compactness (closeness) to one another among the mid-early varieties than early varieties. The early varieties were dispersed in location between one another. This also explains the significant difference in leaf area indices within the early maturity varieties and the insignificant difference within the mid-early varieties in year 2003. Most varieties within mid-early maturity group intercepted most of the light LAI of 2.2 and 2.8. This corresponded to light interception between the ranges of 77 – 85 %. These values are lower than those of year 2002, which were 90 – 95 % of intercepted light and average LAI between 3.0 – 3.8. These, in addition to favourable weather condition accounted for the greater yield in dry matter in 2002 than in the following year.

4.5 Individual leaf areas and leaf generation (numbers) of the varieties

Maximum leaf area (size) in both maturity groups lie between leaf generation 9, 10 and 11, which were also locations of cob leaf of the varieties. Leaf number for the varieties was between 14 and 16 (tables 12 and 13).

Table 12: Leaf area of individual leaves [cm²] of check and core varieties for early maturity group (2002)

Variety	Leaf generation (number)															
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
X Tassilo	**5**	**10**	**20**	**45**	**90**	**153**	**242**	**349**	**455**	**495**	**496**	**442**	**395**	**270**	**143**	**44**
X Symphony	**6**	**13**	**30**	**59**	**112**	**217**	**339**	**474**	**497**	**531**	**474**	**404**	**235**	**147**		
X Diplomat	**7**	**15**	**30**	**57**	**109**	**199**	**296**	**438**	**535**	**551**	**503**	**459**	**359**	**260**	**169**	**95**
X Sagitta	**6**	**13**	**25**	**45**	**107**	**191**	**300**	**427**	**545**	**589**	**563**	**494**	**352**	**270**	**117**	
CV Baxxos	**6**	**14**	**30**	**57**	**123**	**195**	**338**	**501**	**537**	**573**	**495**	**438**	**331**	**174**	**27**	
CV Nescio	**6**	**12**	**27**	**54**	**111**	**204**	**401**	**576**	**627**	**627**	**590**	**510**	**360**	**152**	**9**	
X average	**6**	**13**	**26**	**52**	**105**	**190**	**294**	**422**	**508**	**542**	**509**	**450**	**335**	**237**	**143**	**70**
CV average	**6**	**13**	**29**	**56**	**117**	**200**	**370**	**539**	**582**	**600**	**543**	**474**	**346**	**163**	**18**	

X check variety CV core variety

Individual leaf area (leaf generation) of check and core varieties of early and mid-early maturity groups in year 2003 are indicated in tables 14 and 15. The highest leaf areas were between 9, 10, 11 and 12 in both groups. Total leaf numbers were between 14 and 18 in early and 15 and 16 in mid-early groups.

Table 13: Leaf area [cm²] of individual leaves of check and core varieties of mid-early maturity group (2002)

Variety	Leaf generation (number)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
X Probat	4	11	19	46	94	188	292	446	568	613	572	474	362	191		
X Fjord	6	12	32	66	123	204	294	428	489	539	504	446	350	204	301	123
X Romario	7	14	32	56	119	227	291	462	575	605	619	525	438	299	153	
X Eurostar	7	15	30	58	126	234	341	538	688	743	721	653	565	478	336	152
X Effekt	5	14	30	73	169	302	428	591	653	667	600	512	374	214	150	
CV Lacta	7	16	37	79	156	302	389	508	546	563	505	450	318	157		
CV Pontos	6	16	29	71	143	226	366	477	567	610	596	527	470	327	170	79
CV PR39B50	6	13	30	58	112	221	333	498	592	616	580	508	357	160	190	187
CV Rivaldo	7	14	35	69	132	232	353	470	565	573	575	477	385	217	123	
CV Topper	6	15	32	60	127	238	333	439	558	561	488	428	266	157		
X average	6	13	30	61	127	231	333	489	590	623	599	515	412	267	213	138
CV average	6	15	32	66	132	237	355	487	574	601	563	495	355	217	182	129

X check variety CV core variety

Table 14: Leaf area [cm²] of individual leaves of check and core varieties for early maturity group (2003)

Variety	Leaf generation (number)																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
X Pernel	6	12	21	44	78	152	232	325	455	544	571	533	463	353	284	174	105	63
X Tassilo	6	10	18	40	62	95	137	217	330	466	537	555	495	418	319	231	152	76
XSymphony	7	14	32	66	124	201	334	471	593	628	591	523	420	286	117			
X Ravenna	7	13	27	67	127	211	346	471	612	626	589	509	383	198	24			
X Talman	8	18	39	81	160	279	455	587	653	642	561	439	318	171				
X Early Star	7	14	27	48	87	134	235	373	509	621	655	612	522	426	292	140		
X Ambros	8	13	20	43	84	131	223	364	500	578	588	561	493	413	303	184	91	
X PR39G12	7	15	32	60	102	179	298	438	576	718	690	632	554	423	253	139		
X PR39P49	7	12	26	61	122	224	390	539	663	686	635	518	302	79				
CV Baxxos	8	15	27	54	99	200	288	420	553	656	661	598	500	351	148			
CV Nescio	6	14	30	65	124	222	368	564	676	688	659	591	488	316	154			
X average	7	13	27	57	105	178	294	420	543	612	602	542	439	307	227	174	116	70
CV average	7	15	29	60	112	211	328	492	615	672	660	595	494	334	151			

As the name early and mid-early suggests there were differences in rates of leaf development between early and mid-early maturity varieties in 2002 as shown in the figure 12. Leaf area development in early and mid-early maturity varieties in year 2002 indicated slow initial growth during the first 28 days after germination both maturity groups had similar slow rate of leaf expansion followed by rapid expansion rate in both groups. There was a sharper rise in rate of leaf expansion by the early maturity group than in the mid-early attaining maximum leaf area earlier than mid-early, however levelled off at a plateau lower than the mid-early maturity group.

Table 15: Leaf area [cm²] of individual check and core varieties of mid-early maturity varieties of forage maize in 2003

Variety	Leaf generation (number)															
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
X LG 3226	**6**	**13**	**27**	**56**	**102**	**171**	**262**	**370**	**519**	**637**	**650**	**570**	**505**	**438**	**351**	**254**
X Rivaldo	**6**	**13**	**35**	**69**	**147**	**225**	**356**	**498**	**590**	**622**	**612**	**546**	**463**	**325**	**222**	**109**
X Sandrina	**5**	**13**	**27**	**53**	**101**	**171**	**261**	**433**	**559**	**657**	**648**	**623**	**529**	**412**	**266**	**80**
X Acapulco	**6**	**12**	**27**	**66**	**120**	**187**	**350**	**489**	**575**	**627**	**580**	**491**	**403**	**323**	**214**	**102**
X Topper	**6**	**15**	**34**	**77**	**146**	**216**	**372**	**507**	**598**	**670**	**585**	**579**	**454**	**351**	**175**	
X Flavi	**6**	**12**	**24**	**51**	**100**	**166**	**273**	**445**	**590**	**659**	**646**	**631**	**573**	**494**	**365**	**188**
CV Lacta	**6**	**13**	**27**	**71**	**131**	**219**	**372**	**527**	**647**	**675**	**658**	**559**	**473**	**309**	**110**	
CV Pontos	**7**	**14**	**35**	**74**	**113**	**185**	**316**	**456**	**591**	**692**	**641**	**594**	**524**	**495**	**345**	**190**
CV PR39B50	**7**	**12**	**30**	**58**	**108**	**165**	**288**	**409**	**536**	**597**	**631**	**556**	**483**	**369**	**226**	**87**
X average	**6**	**13**	**29**	**62**	**119**	**189**	**312**	**457**	**572**	**645**	**620**	**573**	**488**	**391**	**266**	**147**
CV average	**6**	**13**	**31**	**68**	**117**	**190**	**325**	**464**	**591**	**655**	**643**	**570**	**493**	**391**	**227**	**139**

Leaf area of mid-early maturity varieties however expanded slower overtaking and attaining a much higher peak (maximum leaf area) than the counterpart. A faster rise in leaf area expansion in the early maturity group enabled them to intercept maximum light necessary for photosynthesis, thereby affording earlier dry matter accumulation. This however was not an indication for attaining higher yields or forage quality than the counterpart due to other factors like leaf senescence rates, leaf duration, total leaf numbers and leaf sizes at the time of harvest.

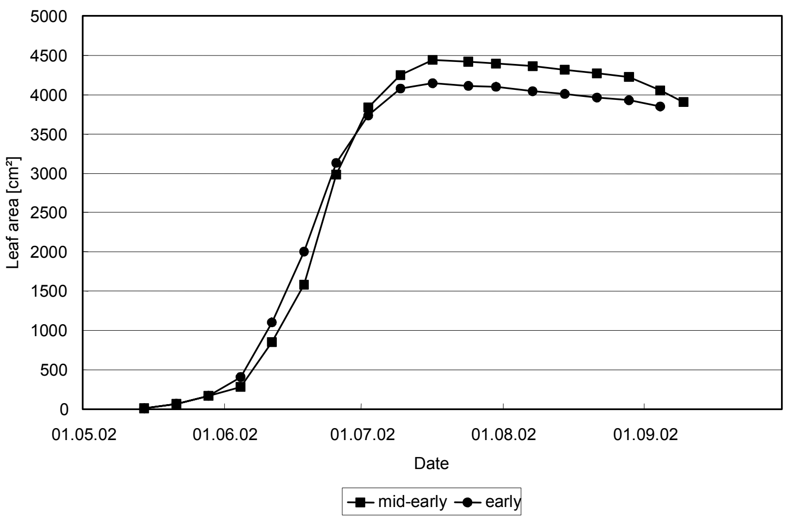


Figure 12: Average leaf area development rates of early and mid-early maturity groups of forage maize in 2002, Berge

4.6 Maximum leaf area

Maximum leaf area at silking of varieties tested in both years of maturity groups and their averages are presented in table 16 and 17. Most of the varieties in both groups attained higher leaf area in 2003 than 2002.

Table 16: Maximum leaf area at silking of early maturity varieties in 2002 and 2003 at location Berge

Early maturity varieties	Leaf area [cm^2]	Leaf area [cm^2]	**Average**
	2002	**2003**	
Pernel	**3655**	**4341**	**3998**
Tassilo	**3630**	**4086**	**3858**
Symphony	**3504**	**4408**	**3956**
Ravenna	**3488**	**4191**	**3839**
Talman	**3878**	**4411**	**4144**
Early Star	**4307**	**4665**	**4486**
Baxxos	**3777**	**4578**	**4177**
Cascadas	**4500**	**5137**	**4818**
Nescio	**4269**	**4890**	**4579**
PR39H32	**5138**	**5128**	**5133**
Ambros	**3995**	**4550**	**4272**
PR39G12	**4815**	**5012**	**4913**
PR39P49	**4463**	**4242**	**4353**
n = 13	**4109**	**4588**	
Average (2002, 2003)			**4348**
LSD α = 5 %	**665**	**411**	**498**

In year 2003 as indicated in table 16 and 17 most of the varieties within both maturity groups showed increase in leaf area as compared to results of year 2002. Although adverse weather conditions could not allow normal leaf senescence to take place, most varieties in early and mid-early maturity groups had already attained maximum leaf area expansion before water deficit and high temperature set in. Here was a significant difference in leaf area within early maturity group and the interaction between the varieties and years was significant in early and mid-early group.

Leaf area and leaf number of a plant affect light interception and photosynthesis hence dry matter production. In several studies differences in total leaf area were associated with changes in leaf size rather than differences in total leaf number (EL-SHARKAWY et al. 1965, IBRAHIM & BUXTON 1981). Total sum of green leaf area was probably more influenced by the size of individual green leaf area of the plant than by the leaf number. In tables 18-21 green leaf area and leaf number of check and core varieties of early and mid-early maturity groups are presented for 2002 and 2003 at harvest time. There are cases in these tables of some varieties with fewer leaf numbers, but having higher total leaf areas, due to larger individual leaf sizes than the counterparts. The tables also show the effect of water deficit in 2003 in shifting leaf zones with largest leaf areas from cob leaf zone, upwards. However leaf number and green leaf area of all the varieties within each maturity group were greatly reduced at the time of harvest due to drought.

Table 17: Maximum leaf area at silking of mid-early maturity varieties in 2002 and 2003 at location Berge

mid-early maturity varieties	Leaf area [cm^2] 2002	Leaf area [cm^2] 2003	Average
LG3226	**4686**	**4483**	**4585**
Rivaldo	**4280**	**4795**	**4538**
Sandrina	**4903**	**4989**	**4946**
Acapulco	**4291**	**4299**	**4295**
Topper	**3811**	**4862**	**4336**
Joxxal	**4331**	**4807**	**4569**
Lacta	**4056**	**5062**	**4559**
Milagro	**4324**	**5009**	**4667**
Montello	**4370**	**4698**	**4534**
Energystar	**4017**	**4657**	**4337**
PR39B50	**4272**	**5225**	**4748**
Pontos	**4672**	**4806**	**4739**
Andino	**4766**	**5260**	**5013**
Flavi	**4502**	**4439**	**4471**
n = 14	**4377**	**4813**	
Average (2002, 2003)			**4595**
LSD α = 5 %	**552**	**790**	**621**

Table 18: Average of green leaf area [cm²] and leaf number from cob leaf position of early check and core varieties of forage maize at harvest time in 2002 at location Berge (03.09.02)

Variety	Leaf location in relation to cob position												Sum LA	Leaf number
	-5	-4	-3	-2	-1	0	1	2	3	4	5	6		
X Tassilo		158	318	426	503	490	455	408	319	179	69		3325	10
X Symphony		24	149	339	461	497	531	480	404	235	147		3267	10
X Diplomat		98	276	401	527	574	502	476	398	286	193	87	3818	11
X Sagitta			270	402	539	588	581	524	393	247	117		3661	9
CV Nescio		33	109	401	567	641	618	607	510	257	152		3895	10
CV Baxxos			46	306	439	514	563	509	453	361	139	13	3343	10
X Average		94	253	392	508	537	517	472	378	237	132	87	3518	10
CV Average		33	77	353	503	577	591	558	481	309	146	13	3619	10

Cob leaf (0) was used as a reference position of the leaf generation, negative numbers (-) indicate leaf generation below cob leaf, positive numbers (+) are leaf generation above cob leaf. Leaves that were fully senesced were not included in table 20.

Table 19: Average of green leaf area [cm²] and leaf number from cob leaf position of mid-early check and core varieties of forage maize at harvest time in 2002 at location Berge (09.09.02)

Variety	Leaf location in relation to cob position												Sum LA	Leaf number
	-5	-4	-3	-2	-1	0	1	2	3	4	5	6		
X Probat		53	165	362	530	580	594	531	439	297	133		3684	10
X Fjord		0	97	161	340	508	533	510	422	322	187	143	3223	11
X Romario		59	208	439	539	590	632	550	468	360	164		4009	10
X Eurostar		70	330	593	691	740	710	634	565	435	297	154	5219	11
X Effekt	39	137	406	535	662	662	616	541	442	249	150		4439	11
X Rivaldo		35	223	295	548	581	592	526	446	312	138		3696	10
CV Topper			183	373	459	559	568	503	436	299	181		3561	9
CV Lacta	29	54	68	320	380	572	535	485	411	217	126		3197	11
CV PR39B50		107	263	249	446	622	581	513	369	160	190	187	3687	11
CV Pontos			269	515	580	607	584	488	404	245	129		3821	9
X Average	39	59	238	397	552	610	613	549	464	329	178	148	4045	11
CV Average	29	80	196	364	466	590	567	497	405	230	157	187	3567	10

Table 20: Average of green leaf area [cm²] and leaf number from cob leaf position of early check and core varieties of forage maize at harvest time in 2003 at location Berge (12.08.2003)

Variety	Leaf location in relation to cob position								Sum LA	Leaf number
	-1	0	1	2	3	4	5	6		
X Pernel			240	396	301	275	173	75	1460	6
X Tassilo	202	249	444	430	338	263	164	76	2166	8
X Symphony		118	408	360	210	165	60		1321	6
X Ravenna		114	269	353	307	178	187	24	1432	7
X Talman			400	235	194	152	50		1031	5
X Early Star			329	329	247	267	203	93	1468	6
X Ambros		214	310	309	242	177	116	83	1451	7
X PR39G12		400	632	554	423	253	139		2401	6
X PR39P49			403	406	418	166	67		1460	5
CV Baxxos			133	370	237	221	69		1030	5
CV Nescio			119	551	453	249	77		1449	5
X Average	202	219	382	375	298	211	129	70	1577	6
CV Average			126	461	345	235	73		1240	5

(0) Cob leaf position as a reference point, (-) Leaf generation below cob leaf, (+) Leaf generation above cob leaf

Table 21: Average of green leaf area [cm²] and leaf number from cob leaf position of mid-early check and core varieties of forage maize at harvest time in 2003 at location Berge (18.08.03)

Variety	Leaf location in relation to cob position								Sum LA	Leaf number
	-1	0	1	2	3	4	5	6		
X LG3226	63	119	252	280	302	263	123	55	1457	8
X Rivaldo		72	200	357	410	323	193	109	1664	7
X Sandrina		85	524	411	367	217	73		1677	6
X Acapulco			178	222	319	174	109		1002	5
X Topper			326	313	199	147	144	65	1194	6
X Flavi	280	251	421	466	494	301	167		2380	7
CV Lacta	90	97	263	388	415	235	64		1552	7
CV Pontos	89	322	263	319	409	307	190		1899	7
CV PR39B50		75	166	200	312	188	71		1012	6
X Average	171	132	317	341	348	238	135	76	1562	7
CV Average	90	165	230	302	378	244	108		1488	7

(0) Cob leaf position as a reference point

(-) Leaf generation below cob leaf

(+) Leaf generation above cob leaf

Green leaf area of surviving leaves of mid-early maturity varieties at harvest total sum of green leaf area of individual variety and corresponding green leaf numbers (Table 21). Cob leaf (0) was used as a reference position of the leaf generation, negative numbers (-) indicate leaf generation below cob leaf, positive numbers (+) are leaf generation above cob leaf. Leaves that were fully senesced were not included in table 15, whose number can be deduced from whole plant total leaf number.

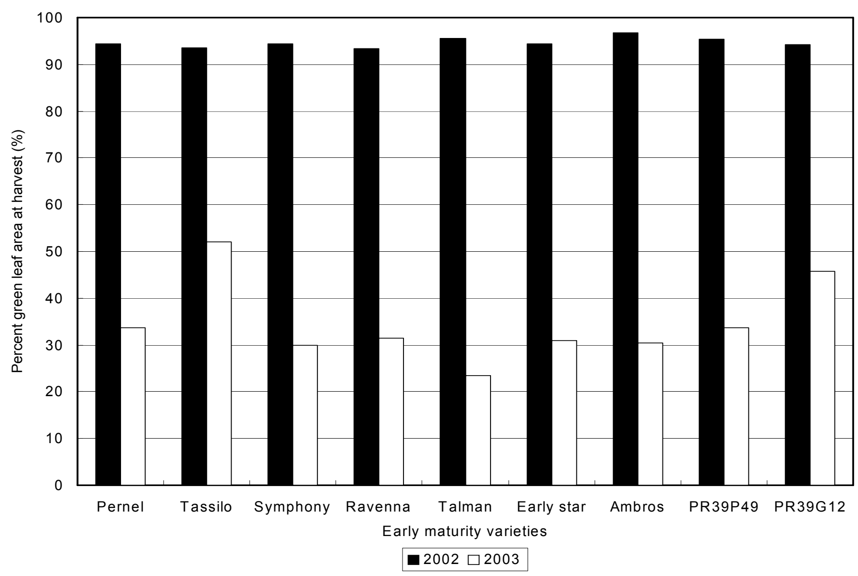


Figure 13: Percent green leaf area at harvest of early check maturity varieties of forage maize in 2002 and 2003, location Berge

The figure 13 shows the percentage of green leaf area of early check maturity varieties of forage maize at the time of harvest in 2003. As the figure indicates, only about 20 – 50 % of the leaves remained vital in most of the varieties within this group. Except for variety Tassilo, which indicated higher percentage of green leaves, all other check varieties fell between 20 and 33 % of green leaves. There were greater fluctuations among the varieties within this group in retaining green leaves than seen in mid-early maturity varieties. The differences in leaf areas within this group were found to be statistically significant. Nearly all the early maturity varieties retained above 90 % of green leaves up to the time of harvest comparing with the results of 2002. This sharp contrast in leaf senescence between these two years was mainly due to varying weather conditions in both years water limitation being the major factor. Water deficit from mid August up to harvest time hastened the rate of leaf senescence in 2003. This caused much reduction in both average total leaf area leaf size and leaf number at the time of harvest compared to the results of 2002. Check and non-check varieties seemed to be equally affected by water deficit although some non-check varieties slightly superseded the check varieties in percentage green leaf area at harvest time.

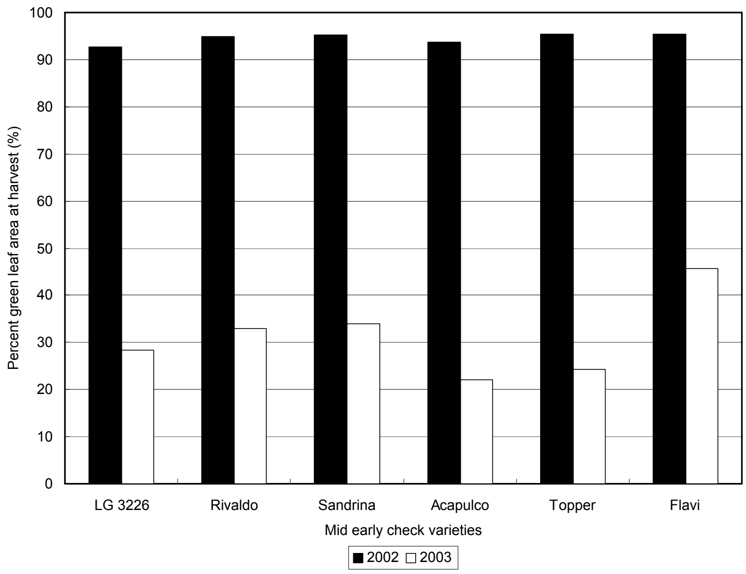
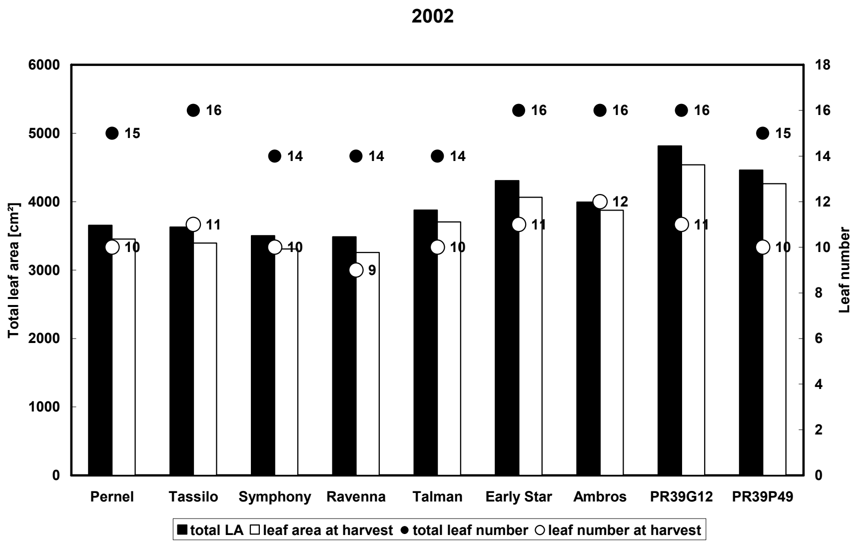


Figure 14: Percent green leaf area at harvest of mid-early check maturity varieties of forage Maize in 2002 and 2003, location Berge

The figure 14 shows the percentage of green leaf at the time of harvest in mid-early maturity varieties of forage maize. As was the case with early maturity group percentage green leaf area in mid-early maturity group was greatly reduced below 50 %. Most varieties within this group had between 20 and 35 % of green leaf area at harvest time. Check varieties showed no advantage over non-check varieties.



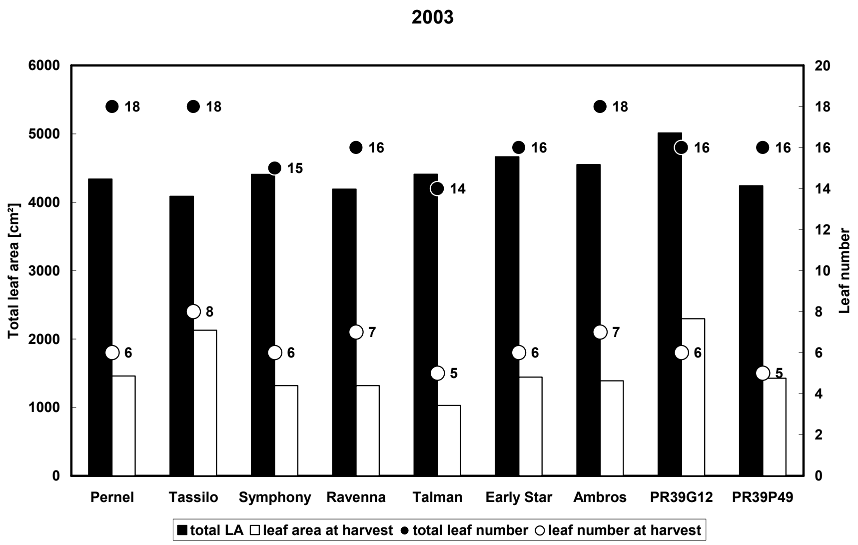
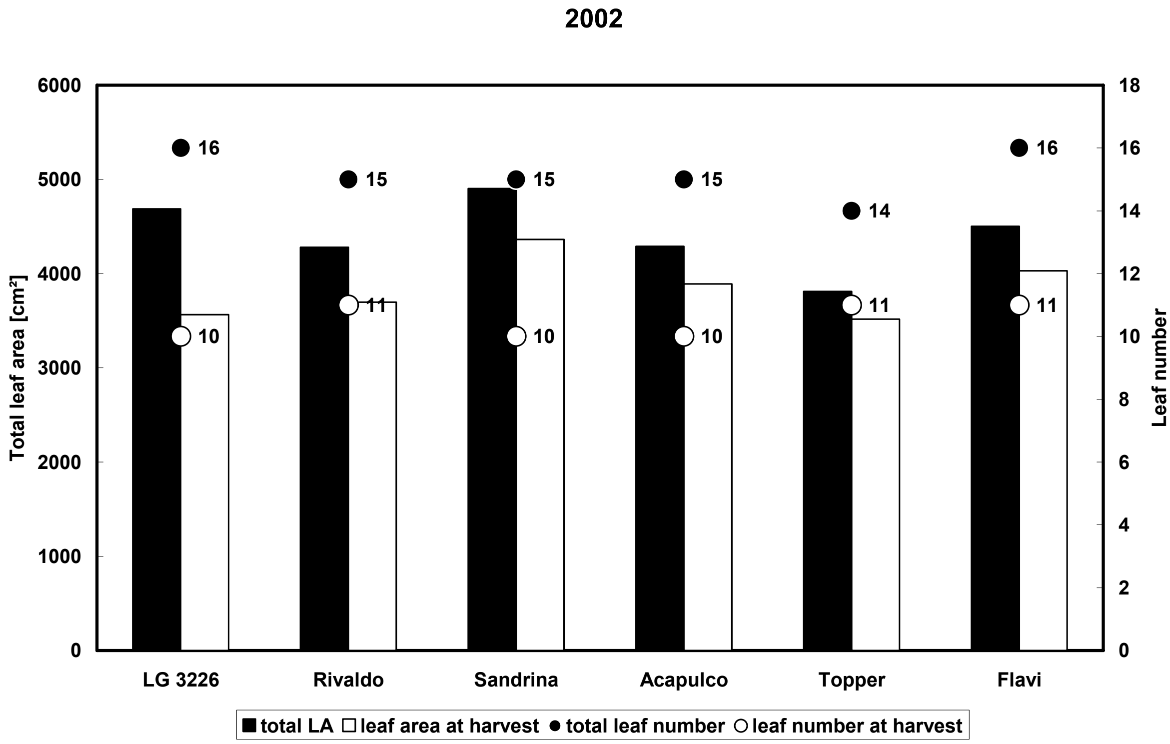


Figure 15: Leaf area of all leaves per plant (max.) and leaf number (total.), green leaf area and green leaf number at harvest of early maturity check varieties of forage Maize in 2002 and 2003, Berge

The figure 15 shows leaf area of all leaves (maximum) that was attained for each early maturity check varieties and the corresponding total leaf number (leaf generation). The period of maximum leaf area and total leaf number also corresponded to the period of flowering. Green leaf area and green leaf number at harvest time showed the extent at which reduction in area and number of the leaves took place within the group in each year as affected by varying environmental conditions. The maximum sum of green leaf area was reduced to between 1500 and 2500 cm², total leaf number was between 5 and 8 and between 9 and 12 leaves dried per plant.



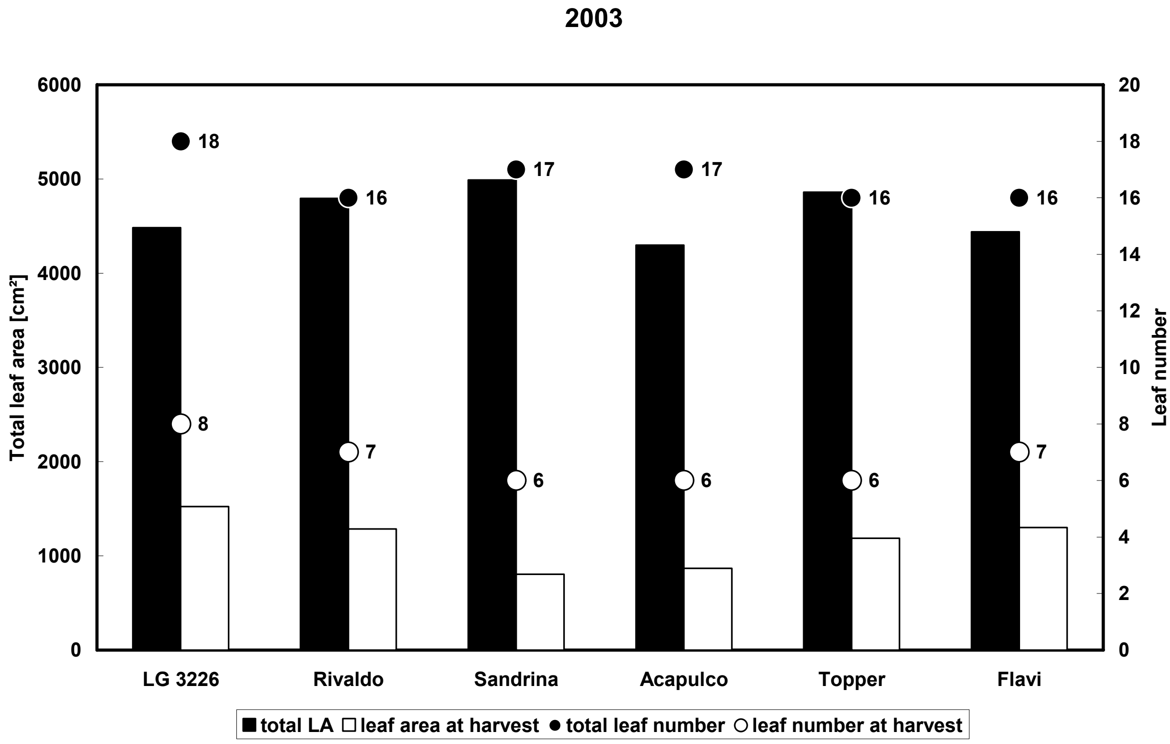


Figure 16: Leaf area of all leaves per plant (max.) and leaf number (total), green leaf area and green leaf number at harvest of mid-early maturity check varieties of forage maize in 2002 and 2003, location Berge

Represented in figure 16 are leaf area of all leaves per plant (maximum) and corresponding total leaf number of mid-early check varieties (2003). Stay green character could also be expressed through the maintenance of green leaf area up to harvest time by a variety.

Maximum leaf area ranged between 4000 and 5000 cm², while the total leaf number was between 16 and 18. At harvest the maximum sum of leaf area was reduced to between 1000 and 2500 cm² and the total leaf number to between 6 and 8. Leaf senescence left 9 until 11 dried leaves per plant. The number of senesced leaves was higher in varieties with higher total leaf numbers than in varieties with lower total leaf numbers. For instance check varieties Sandrina and Acapulco both had total leaf numbers of 17, lost 11 to senescence and had 6 vital and green leaves each at harvest, while check variety Rivaldo and Flavi, both had total leaf numbers of 16 each, lost 9 and had 7 green and vital leaves at harvest.

Table 22: Leaf area, dry mass and specific leaf area of check variety Symphony of early maturity group

Cob position	Leaf generation	Leaf area [cm²]	Dry weight [g]	SLA [cm^2 g^{-1} DM]
-5	**5**	**127.5**	**0.28**	**455**
-4	**6**	**220.2**	**0.99**	**222**
-3	**7**	**347.2**	**1.59**	**218**
-2	**8**	**502.5**	**2.50**	**201**
-1	**9**	**651.8**	**3.22**	**202**
0	**10**	**621.5**	**3.39**	**183**
1	**11**	**611.7**	**3.49**	**175**
2	**12**	**513.3**	**2.66**	**193**
3	**13**	**372.3**	**2.05**	**182**
4	**14**	**277.1**	**1.47**	**189**
5	**15**	**107.1**	**0.54**	**198**

Cob position: (o) is cob-leaf, (-) leaf below the cob-leaf, (+) leaf above cob-leaf, x leaf generation that dried off, not weighed

Table 22 shows in connection with figures 17, 18, 19 and 20, specific leaf area (SLA cm² g^{-1}) at individual plant level, in relation to leaf area (cm²), dry matter weight (g) and leaf generation. Cob leaf (0) was taken as reference position on plant leaf generation.

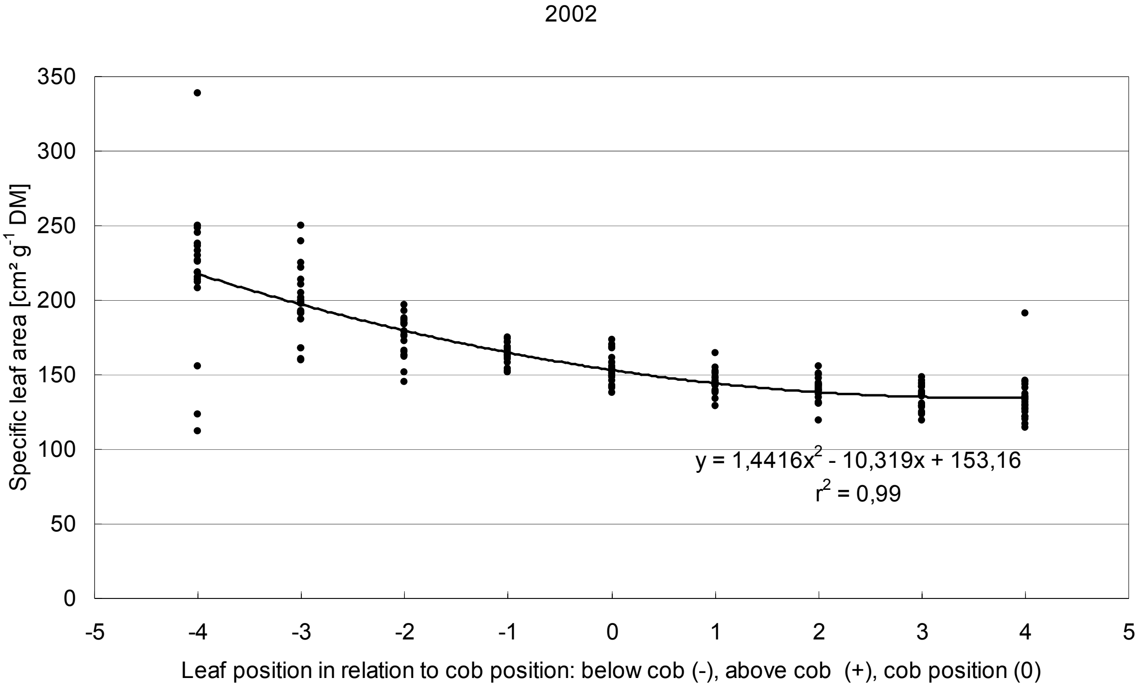


Figure 17: Specific leaf area (SLA) of early maturity varieties (n=21) in 2002, Berge

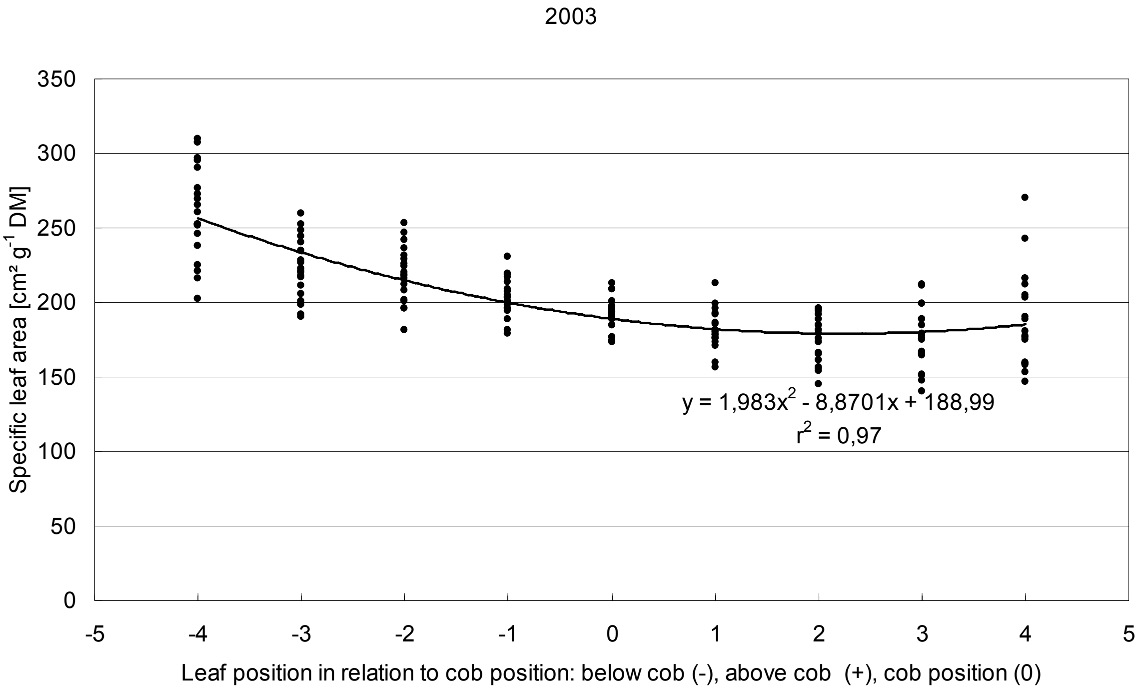


Figure 18: Specific leaf area (SLA) of early maturity varieties (n=18) in 2003, Berge

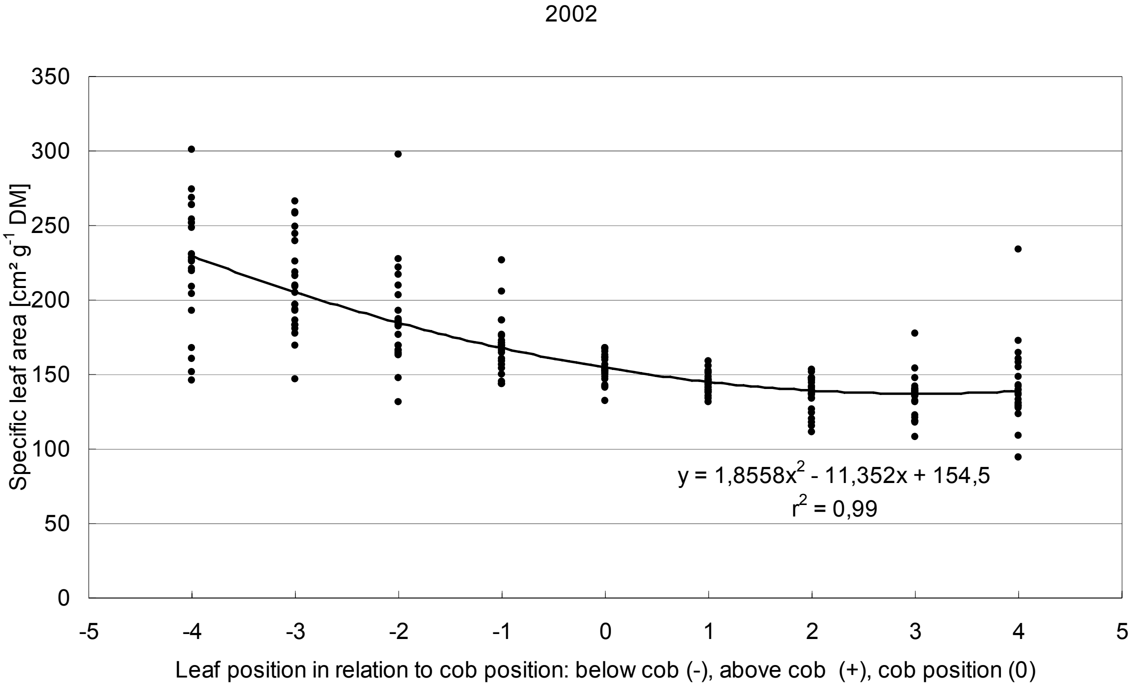


Figure 19: Specific leaf area (SLA) of mid-early maturity varieties (n=22) in 2002, Berge

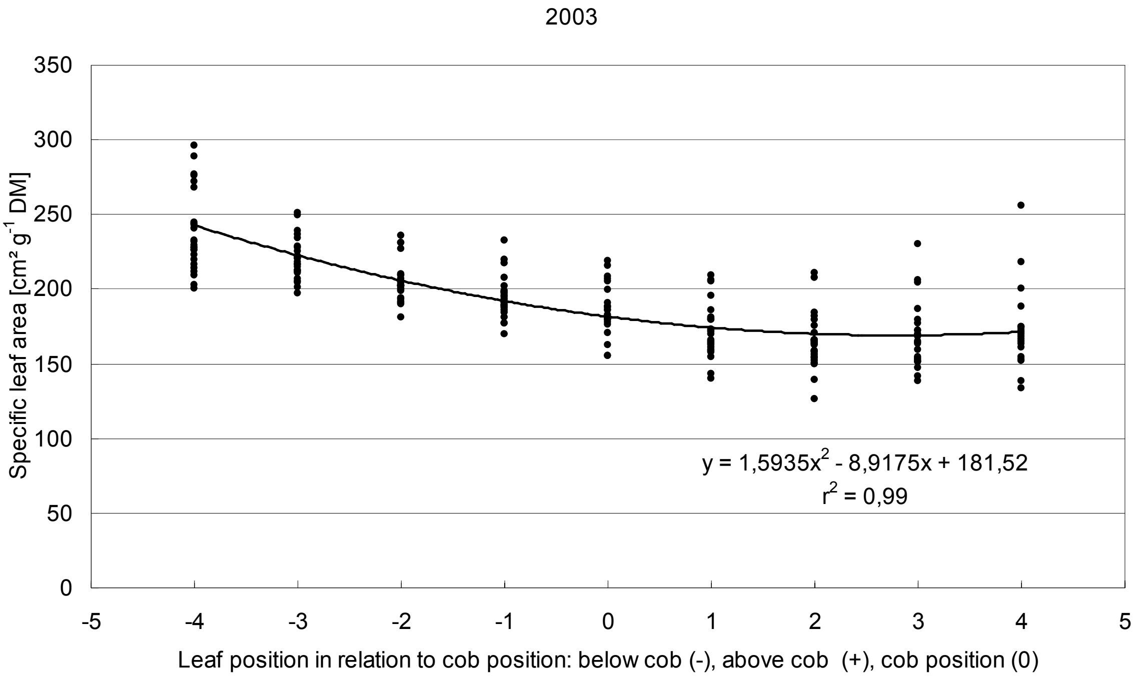
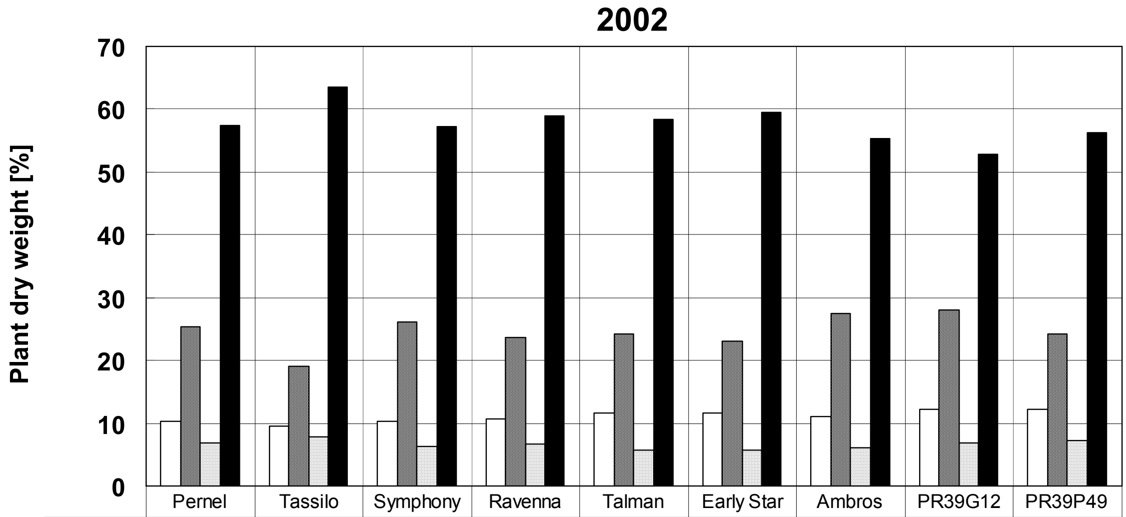


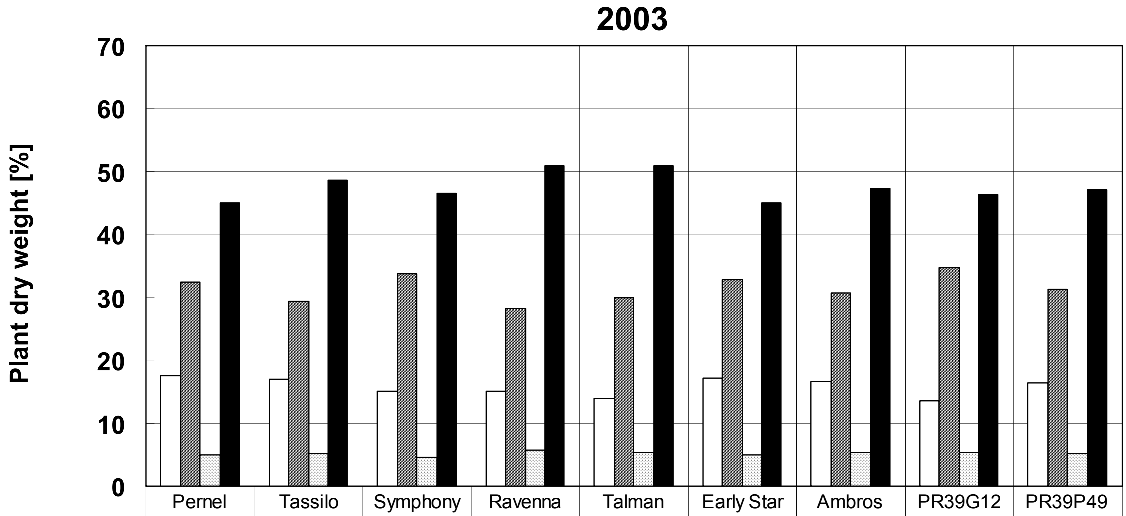
Figure 20: Specific leaf area (SLA) of mid-early maturity varieties (n=25) in 2003, Berge

Figures 17 - 20 indicate specific leaf area (SLA) of early and mid-early maturity groups of forage maize tested in years 2002 and 2003. Senesced leaves that fell off the plants and missing were not included in the measurements.

Figures 21 and 22 compare dry weight of plant components (leaf, stem, cob leaf and cob dry weight expressed as percent of whole plant dry weight) of early and mid-early check varieties of forage maize for 2002 and 2003. There was a reduction in cob and cob leaf dry weight an increase in leaf and stem dry weight in 2003 in both maturity groups.

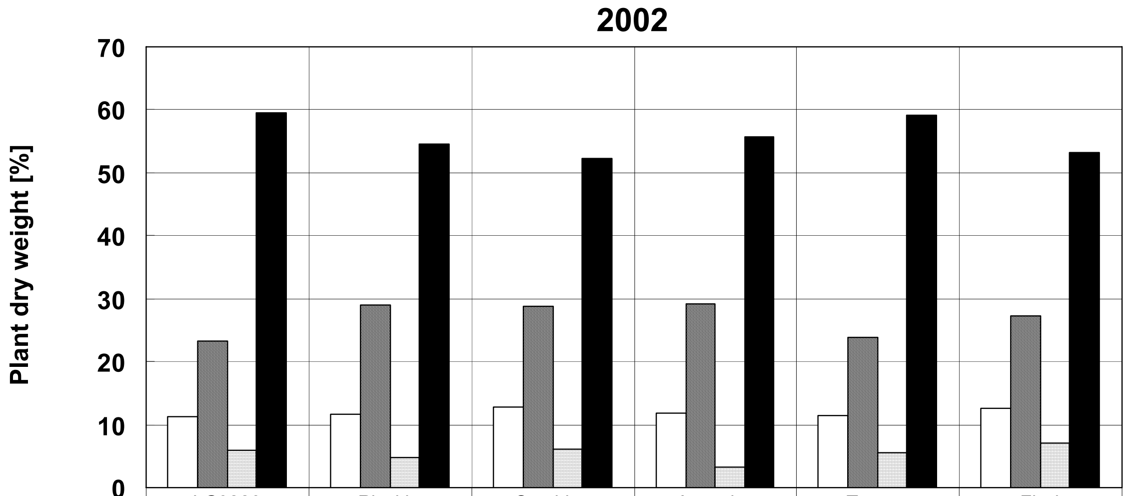


	Pernel	Tassilo	Symphony	Ravenna	Talman	Early Star	Ambros	PR39G12	PR39P49
□ Leaf	10,3	9,5	10,3	10,7	11,6	11,7	11,1	12,2	12,3
■ Stem	25,4	19,1	26,2	23,7	24,2	23,1	27,4	28,0	24,3
□ Cob leaf	6,9	7,8	6,3	6,7	5,8	5,7	6,1	6,9	7,2
■ Cob	57,4	63,6	57,2	58,9	58,4	59,5	55,4	52,9	56,2

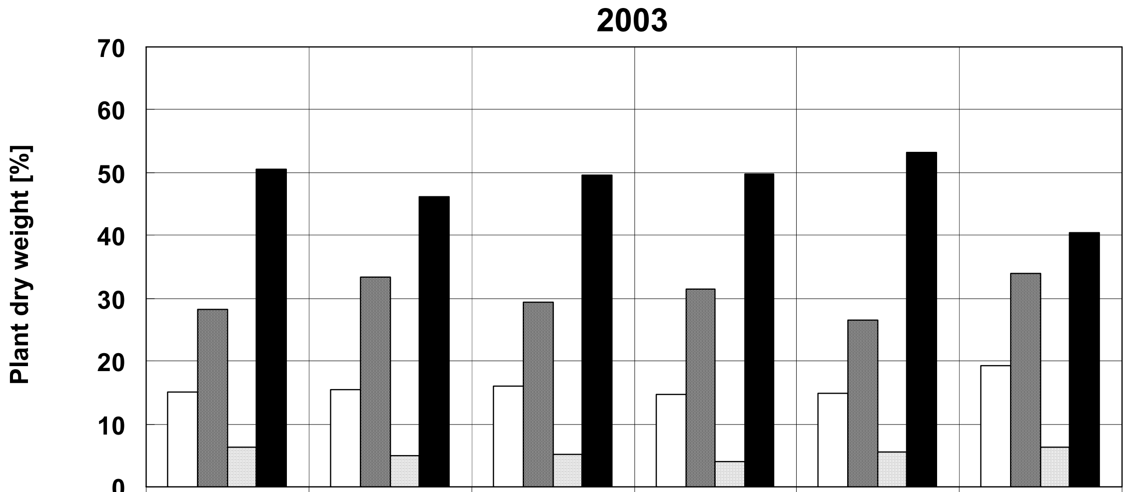


	Pernel	Tassilo	Symphony	Ravenna	Talman	Early Star	Ambros	PR39G12	PR39P49
□ Leaf	17,5	16,9	15,1	15,1	13,9	17,2	16,6	13,6	16,4
■ Stem	32,5	29,3	33,7	28,3	29,9	32,9	30,8	34,7	31,2
□ Cob leaf	4,9	5,1	4,6	5,7	5,3	4,9	5,3	5,3	5,2
■ Cob	45,1	48,7	46,6	50,9	50,9	45,0	47,3	46,4	47,2

Figure 21: Plant dry weight [%] of check varieties (early maturity group)



	LG3226	Rivaldo	Sandrina	Acapulco	Topper	Flavi
□ Leaf	11,3	11,7	12,8	11,9	11,4	12,5
■ Stem	23,2	29,0	28,8	29,2	23,8	27,3
□ Cob leaf	6,0	4,7	6,1	3,3	5,6	7,0
■ Cob	59,5	54,6	52,3	55,6	59,2	53,2



	LG3226	Rivaldo	Sandrina	Acapulco	Topper	Flavi
□ Leaf	15,0	15,4	16,0	14,6	14,8	19,2
■ Stem	28,2	33,4	29,3	31,5	26,5	34,0
□ Cob leaf	6,3	5,0	5,1	4,1	5,5	6,3
■ Cob	50,5	46,2	49,6	49,8	53,2	40,5

Figure 22: Plant dry weight [%] of check varieties (mid-early maturity group)

Statistical analysis

Statistical analysis showed significant differences in dry matter yield, dry matter content, energy yield and leaf area. All the pooled values showed significant differences within the group. The effect of variation in year on the given parameters was significant except in crude protein, which was insignificant even in the pooled values. Like in mid-early maturity varieties, there were significant differences in all pooled values as well as in year * treatment interactions among varieties. Therefore unless otherwise stated only the means (average values) of the parameters tested will be discussed, significant differences of the parameters will be discussed in detail.

Table 23: Variation analysis for early maturity varieties of forage maize tested in year 2002 and 2003

Early maturity group (n=13)		F-value			
Parameters	**Unit**	**Within varieties**	**Between years**	**Pooled error within varieties**	**Pooled error between years**
Dry matter yield	**[dt ha^{-1}]**	**4.043***	**1904.256***	**5.523***	**2601.047***
Dry matter content	**[%]**	**3.365***	**66.871***	**14.276***	**283.720***
CV Starch yield	**[dt ha^{-1}]**	**1.045 ns**	**16.907***	**9.663**	**156.400***
Starch content	**[%]**	**0.962 ns**	**19.873***	**7.258***	**149.915***
Energy yield	**[NEL MJ ha^{-1}]**	**3.581***	**1789.161***	**6.095***	**3045.222***
Crude fibre	**[%]**	**1.657 ns**	**61.049***	**6.853***	**252.520***
Crude protein	**[%]**	**0.841 ns**	**1.533 ns**	**2.009***	**3.661 ns**
Leaf area (BBCH 55/65)	**[cm²]**	**6.636***	**28.473***	**9.127***	**39.159***

* Significant difference: 5 %

Table 24: Variation analysis (NIRS) for mid-early maturity varieties of forage maize tested in year 2002 and 2003

Mid-early maturity group (n = 14)		F-value			
Parameters	**Unit**	**Within varieties**	**Between years**	**Pooled error within varieties**	**Pooled error between years**
Dry matter yield	**[dt ha^{-1}]**	**1.720 ns**	**711.551***	**3.899***	**1613.380***
Dry matter content	**[%]**	**2.339 ns**	**50.995***	**17.898***	**390.151***
Starch yield	**[dt ha^{-1}]**	**1.460 ns**	**373.448***	**5.177***	**1324.096***
Starch content	**[%]**	**2.073 ns**	**94.408***	**6.956***	**316.765***
Energy yield	**[NEL MJ ha^{-1}]**	**1.544 ns**	**652.555***	**4.948***	**2090.839***
Energy content	**[NEL MJ kg^{-1}]**	**1.986 ns**	**237.300***	**5.400***	**645.314***
Crude fibre	**[%]**	**1.772 ns**	**155.727***	**4.535***	**398.623***
Crude protein	**[%]**	**1.586 ns**	**10.251***	**3.408***	**22.023***
Leaf area (BBCH 55/65)	**[cm²]**	**1.107 ns**	**16.113***	**1.569 ns**	**22.830***

*Significant difference: 5 %

According to analysis of variance mid-early maturity varieties there were insignificant differences in all parameters tested within the group (table 24). The results of the analysis showed significant differences in all the parameters tested between the two years. Pooled values indicated significant differences within the group and between the years, in all the parameters tested, except for leaf area within the group, which was insignificant. The effect of variation in varieties within this group was insignificant. This showed that changes in environmental (weather) conditions from year to year played a significant role in shaping yield and forage quality of maize varieties.

In the early maturity varieties (table 23) unlike the mid-early varieties, whereby there were no effects of variety within the group on all the parameters given here. However significant differences were seen in dry matter yield, dry matter content, energy content and leaf area. All the pooled values showed significant differences within the group. The effect of variation in year on the given parameters was significant except in crude protein, which was insignificant even in the pooled values.

4.7 Dry matter yield and dry mass content

Table 25 shows dry matter yield and dry matter content of early maturity group of silage maize in years 2002 and 2003.

Table 25: Dry matter yield and dry matter content of 13 early maturity varieties of silage maize tested in 2002 and 2003 and 3 core varieties tested in the 3 years 2002-2004, location Berge

Variety	Dry matter yield [dt ha^{-1}]			Dry matter content [%]		
	2002	**2003**	**2004**	**2002**	**2003**	**2004**
Pernel	**177.2**	**111.5**		**36.18**	**38.95**	
Tassilo	**167.9**	**105.7**	**154.0**	**36.60**	**43.45**	**30.28**
Symphony	**175.0**	**100.1**		**32.85**	**38.58**	
Ravenna	**168.1**	**99.7**		**37.35**	**40.95**	
Talman	**180.9**	**103.9**		**35.43**	**43.13**	
Early Star	**171.3**	**100.3**		**33.93**	**38.60**	
Baxxos	**184.4**	**101.3**	**159.5**	**36.67**	**37.85**	**29.95**
Cascadas	**183.0**	**107.0**		**33.45**	**35.92**	
Nescio	**186.0**	**113.1**	**160.4**	**33.33**	**41.70**	**27.67**
PR39H32	**175.2**	**99.1**		**30.33**	**34.60**	
Ambros	**186.7**	**117.7**		**34.87**	**39.12**	
PR39G12	**185.3**	**104.7**		**31.70**	**38.82**	
PR39P49	**166.7**	**98.7**		**33.48**	**40.45**	
n = 13	**177.5**	**104.8**		**34.32**	**39.39**	
n = 3			**158.0**			**29.30**
LSD ($\alpha = 0.05$)	**10.6**	**10.0**	**12.9**	**1.52**	**2.68**	**1.41**

Of all the varieties tested in the two experiments 13 varieties were tested in both years, from which analysis of variance was made. Varieties that were tried in the three years 2002, 2003 and 2004 (core varieties) are included in table 25 for comparison of the changes in dry matter yield and dry matter content over the three years.

Table 26: Dry matter yield and dry matter content of 14 mid-early maturity varieties of silage maize tested in 2002 and 2003 and 5 core varieties tested in the 3 years 2002, 2003 and 2004, location Berge

Variety	Dry matter yield [dt ha^{-1}]			Dry matter content [%]		
	2002	**2003**	**2004**	**2002**	**2003**	**2004**
LG3226	**192.2**	**135.5**		**39.00**	**47.80**	
Rivaldo	**180.0**	**122.0**	**175.2**	**37.63**	**39.80**	**31.53**
Sandrina	**186.2**	**123.2**		**35.13**	**42.85**	
Acapulco	**188.1**	**132.3**		**36.50**	**41.85**	
Topper	**180.8**	**117.1**	**176.6**	**39.23**	**46.20**	**32.15**
Joxxal	**175.9**	**115.8**		**37.95**	**48.40**	
Lacta	**176.2**	**134.4**	**185.1**	**40.25**	**44.50**	**34.15**
Milagro	**189.8**	**129.9**		**40.63**	**43.45**	
Montello	**175.4**	**124.4**		**38.60**	**45.63**	
Energystar	**179.4**	**127.0**		**38.53**	**43.15**	
PR39B50	**184.2**	**118.0**	**175.8**	**37.53**	**47.20**	**31.40**
Pontos	**172.3**	**131.9**	**189.5**	**37.90**	**42.35**	**32.13**
Andino	**182.0**	**122.1**		**41.07**	**42.63**	
Flavi	**193.5**	**128.4**		**34.35**	**36.48**	
n = 14	**182.6**	**125.9**		**38.16**	**43.74**	
n = 5			**180.4**			**32.27**
LSD α=5 %	**10.9**	**10.2**	**15.0**	**2.16**	**2.05**	**1.44**

Dry matter yield and dry matter content of 14 mid-early maturity varieties of silage maize tried in years 2002 and 2003 and 5 varieties tried for the three years (2002-2004) are shown in table 26. The complete table for all the varieties tested in each year is in Appendix 1

However, there was no significant difference within the varieties, only between the two years was a significant difference found between the varieties. Similarly, higher average dry matter content between the maturity groups was found in mid-early maturity group than in early maturity group. Although weather conditions at the research station for both years sharply contrasted, namely one being more favourable than the other, yet the relation of average dry matter yield and dry matter content between the maturity groups did not alter. As it was the case in year 2002, the average dry matter yield and content in year 2003 for mid-early maturity varieties were higher than those of early maturity varieties. However the average dry matter yield for year 2003 of early maturity varieties (105.0 dt ha^{-1}) and mid-early maturity varieties (125.4 dt ha^{-1}) were much lower than for year 2002: early 176.5 dt ha^{-1} and mid-early 181.5 dt ha^{-1}. The average dry matter content for year 2003 for both early (39.29 %) and mid-early (43.61 %) maturity varieties were higher than the values of year 2002 of 34.4 % and 38.2 % respectively.

Dry matter yield (dt ha^{-1}): The average dry matter yield for early maturity varieties in year 2002 was 176.5 dt ha^{-1} and 105 dt ha^{-1} in 2003. However, the average dry matter yield for year 2002 was much higher than that of 2003, due to more favourable weather conditions for growth in 2002. There was a significant difference in dry matter yield within this group for each year. The interaction between the varieties and the years was significant. Differences in dry matter yield within the group are a result of genotypic differences in yield potentials of individual varieties within the group.

Dry matter content (%): The average dry matter content for early maturity varieties was 34.4 % in 2002 and 39.29 % in 2003. There was a significant difference in dry matter content within this group and between the years. Genotypic and environmental variations affected both dry matter yield and dry matter content in both years.

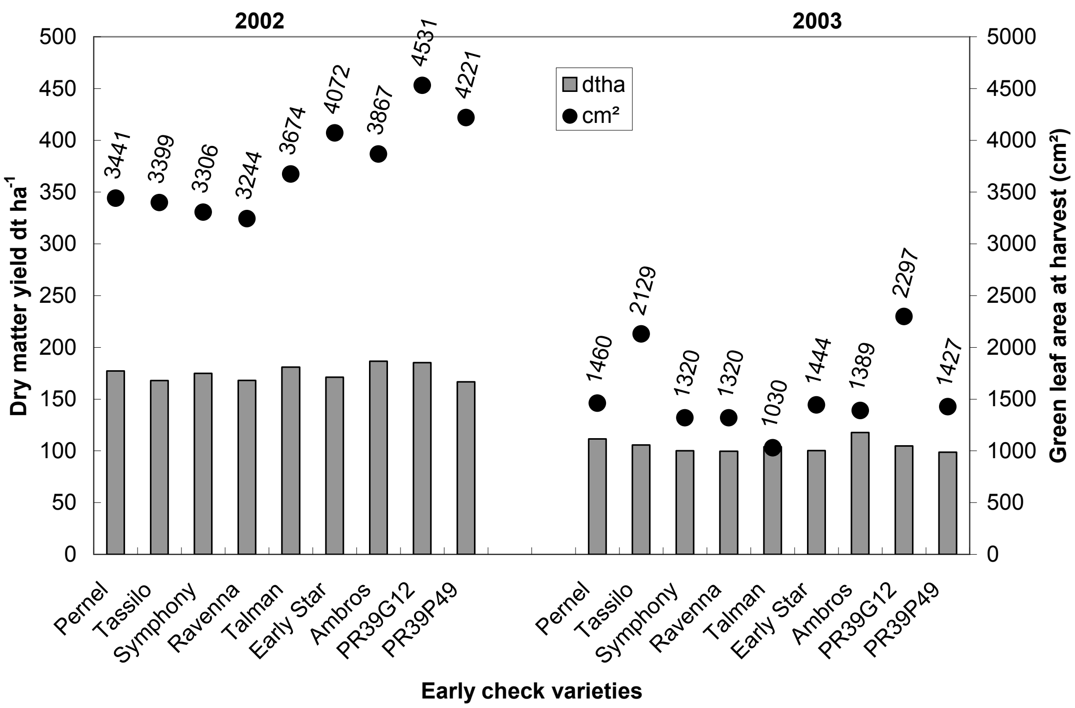


Figure 23: Dry matter yield and green leaf area of early maturity varieties of forage maize at harvest in 2002 and 2003, Berge

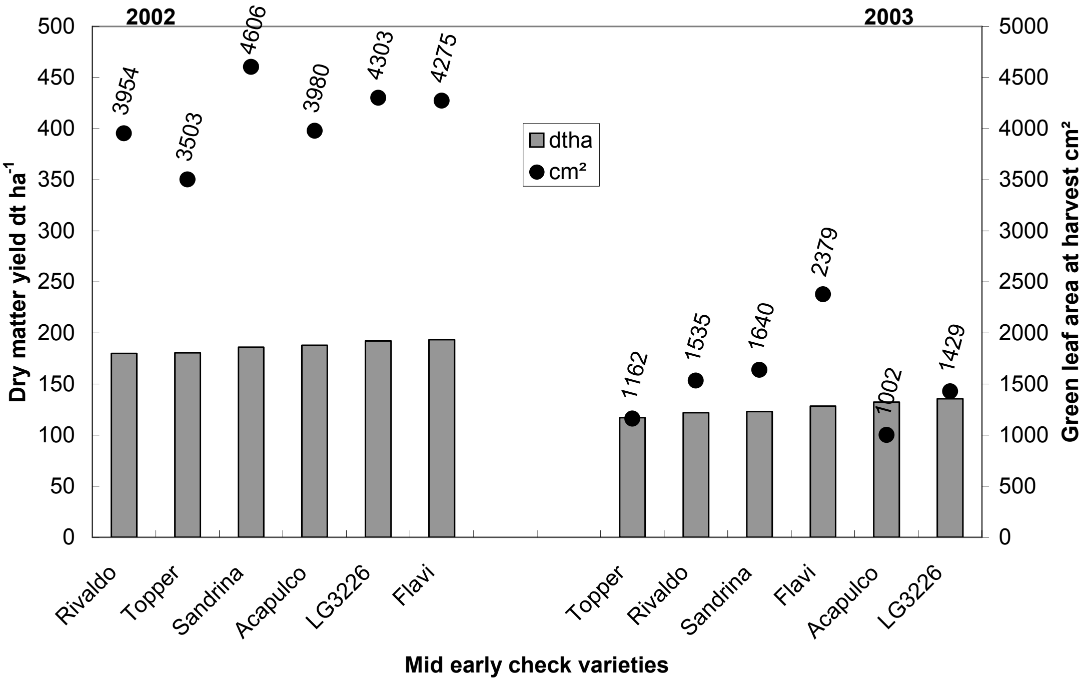


Figure 24: Dry matter yield and green leaf area of mid-early maturity varieties of forage maize at harvest in 2002 and 2003, Berge

Dry matter yield and green leaf area at harvest of early and mid-early maturity check varieties in 2002 and 2003 are presented in figures 23 and 24. Whether maintaining high green leaf area at harvest contributed to improved dry matter yield, especially under unfavourable environmental conditions (water deficit), was a question the figures were seeking to answer.

4.8 Forage quality

Forage quality of maturity groups tested in years 2002 and 2003 differed between the years. Early maturity varieties showed significant differences not only in dry matter yield, dry matter content and leaf area, but also in energy yield. The rest of the parameters tested like crude fibre, crude protein, starch content and starch yield showed insignificant difference within the group. In both groups however, all tested parameters indicated significant differences in year * variety interaction except in the early group, which showed insignificant difference in crude protein content. Pooled values for both years showed significant differences for all the parameters tested except for the crude protein content in the early group, which was insignificant.

Forage value of silage maize depends on the increase in dry matter content. Concentration of organic substances in the cob and of importance also is the digestibility so that the intake of nutrients may increase in ruminants (GROSS 1986, HEPTING 1992, EDER 1993).

Of great importance in evaluating silage maize for forage is the energy production or energy yield (GJ NEL ha^{-1}), dry matter content of whole plant and starch content in the dry matter HEPTING 1994).

Increase in starch yield increases the relative energy yield, which in turn gives high forage value. Starch content in the whole plant is determined by its content in the cob. It increases with development of cob

Quality parameters of silage maize of maturity group early and mid-early varieties in regional variety trial of Brandenburg in 2002, 2003 and 2004 (core varieties) at location Berge.

Table 27: Starch yield and starch content of early maturity varieties of maize in 2002, 2003 and 2004, location Berge

Early maturity varieties	Starch yield [dt ha^{-1}]			Starch content [%]		
	2002	**2003**	**2004**	**2002**	**2003**	**2004**
Pernel	**61.0**	**28.5**		**34.44**	**25.52**	
Tassilo	**59.0**	**36.8**	**47.6**	**35.23**	**34.71**	**30.90**
Symphony	**57.8**	**28.5**		**33.24**	**28.61**	
Ravenna	**65.9**	**34.8**		**39.24**	**34.91**	
Talman	**62.7**	**35.8**		**34.68**	**34.32**	
Early Star	**64.5**	**27.2**		**37.57**	**27.08**	
Baxxos	**70.1**	**22.0**	**48.5**	**37.93**	**21.69**	**30.40**
Cascadas	**71.3**	**26.2**		**38.95**	**24.50**	
Nescio	**68.7**	**40.8**	**53.5**	**36.93**	**36.08**	**33.32**
PR39H32	**61.8**	**21.2**		**35.38**	**21.27**	
Ambros	**62.4**	**32.2**		**33.45**	**27.34**	
PR39G12	**57.6**	**31.4**		**31.12**	**29.77**	
PR39P49	**62.5**	**29.3**		**37.45**	**29.70**	
n = 13	**63.5**	**30.4**		**35.82**	**28.88**	
n = 3			**49.9**			**31.54**
LSD $\alpha = 0.05$	**6.4**	**6.3**	**6.7**	**3.40**	**4.69**	**2.86**

Table 27 shows starch yield and starch content for the silage maize varieties of early maturity group, which were tested in both years 2002 and 2003. The results of year 2004 show varieties that were tested in the three years (core varieties) and are used for the purpose of comparing the results of three years test of these varieties. Starch yield and starch content for mid-early maturity varieties tested in 2002 and 2003 and core varieties (2004) are indicated in table 28. Significant differences were found in starch yield and starch content between the years in both maturity groups (table 23 and 24). Core varieties also showed significant differences in the three years analysis.

Table 28: Starch yield and starch content of mid-early maturity varieties of forage maize in 2002, 2003 and 2004, location Berge

Varieties	Starch yield [dt ha^{-1}]			Starch content [%]		
	2002	**2003**	**2004**	**2002**	**2003**	**2004**
LG3226	**77.1**	**42.4**		**40.09**	**31.26**	
Rivaldo	**67.8**	**35.6**	**55.6**	**37.76**	**29.15**	**31.71**
Sandrina	**62.5**	**37.8**		**33.62**	**30.72**	
Acapulco	**73.1**	**47.2**		**38.89**	**35.58**	
Topper	**75.5**	**38.4**	**61.4**	**41.81**	**32.65**	**34.79**
Joxxal	**63.4**	**31.9**		**36.05**	**27.55**	
Lacta	**70.1**	**46.7**	**61.7**	**39.85**	**34.71**	**33.20**
Milagro	**74.6**	**34.8**		**39.30**	**26.89**	
Montello	**67.0**	**37.8**		**38.30**	**30.37**	
Energystar	**68.3**	**40.6**		**38.13**	**31.82**	
PR39B50	**74.8**	**39.2**	**62.2**	**40.60**	**33.25**	**35.41**
Pontos	**64.7**	**43.6**	**57.6**	**37.60**	**33.07**	**30.43**
Andino	**68.9**	**36.7**		**37.85**	**30.07**	
Flavi	**72.6**	**32.5**		**37.55**	**25.27**	
n = 14	**70.0**	**38.9**		**38.39**	**30.88**	
n = 5			**59.7**			**33.11**
LSD α=5 %	**6.8**	**5.9**	**7.8**	**2.87**	**3.40**	**3.25**

Energy yield and energy content are important parameters in evaluating the quality of forage maize. In table 29 early maturity varieties tested in 2002 and 2003 and core varieties (2004) are shown. The average energy yield for year 2002 was 115.1 GJ NEL ha^{-1} and 61.7 GJ NEL ha^{-1} in 2003, for the early varieties tested in both years (13 varieties). The average energy content was 6.52 MJ NEL kg^{-1} (2002) and 5.87 MJ NEL kg^{-1} (2003). Significant differences existed between the years in energy yield and energy content (table 23 and 24).

In table 30 is energy yield and energy content of mid-early maturity varieties tested in the years 2002 and 2003 and core varieties (2004). The average energy yield for 2002 was 121.2 GJ NEL ha^{-1} and 74.5 GJ NEL ha^{-1} in 2003. The average energy content was 6.64 MJ NEL kg^{-1} (2002) and 5.92 MJ NEL kg^{-1} (2003). Significant differences were found between the years in energy yield and energy content.

Correlation coefficients between maize forage parameters in early and mid-early maturity groups in 2002 and 2003 trials at location Berge (tables 31, 32, 33 and 34).

Table 29: Energy yield and energy content of early maturity varieties of forage maize in 2002, 2003 and 2004, location Berge

Early maturity varieties	Energy yield [GJ NEL ha^{-1}]			Energy content [MJ NEL kg^{-1}]		
	2002	**2003**	**2004**	**2002**	**2003**	**2004**
Pernel	**117.7**	**63.9**		**6.64**	**5.72**	
Tassilo	**112.9**	**66.2**	**98.6**	**6.73**	**6.26**	**6.40**
Symphony	**113.6**	**58.2**		**6.50**	**5.82**	
Ravenna	**112.2**	**62.0**		**6.68**	**6.22**	
Talman	**117.9**	**64.2**		**6.52**	**6.18**	
Early Star	**112.3**	**58.4**		**6.55**	**5.82**	
Baxxos	**122.9**	**57.6**	**101.0**	**6.66**	**5.68**	**6.33**
Cascadas	**118.6**	**58.5**		**6.48**	**5.46**	
Nescio	**123.5**	**72.4**	**103.6**	**6.64**	**6.41**	**6.46**
PR39H32	**110.1**	**55.0**		**6.31**	**5.57**	
Ambros	**124.4**	**70.0**		**6.67**	**5.94**	
PR39G12	**119.4**	**61.8**		**6.44**	**5.89**	
PR39P49	**111.9**	**60.0**		**6.71**	**6.07**	
n= 13	**115.1**	**61.7**		**6.52**	**5.87**	
n = 5			**101.0**			**6.40**
LSD α =5 %	**7.6**	**6.7**	**9.2**	**0.20**	**0.28**	**0.19**

Table 30: Energy yield and energy content of mid-early maturity varieties of forage maize in 2002, 2003 and 2004, location Berge

Mid-early maturity varieties	Energy yield [GJ NEL ha^{-1}]			Energy content [MJ NEL kg^{-1}]		
	2002	**2003**	**2004**	**2002**	**2003**	**2004**
LG3226	**129.7**	**81.1**		**6.75**	**5.99**	
Rivaldo	**119.9**	**71.5**	**112.1**	**6.66**	**5.86**	**6.40**
Sandrina	**118.8**	**72.2**		**6.38**	**5.86**	
Acapulco	**124.9**	**82.0**		**6.65**	**6.19**	
Topper	**123.7**	**70.4**	**112.3**	**6.85**	**6.01**	**6.37**
Joxxal	**113.2**	**65.0**		**6.44**	**5.61**	
Lacta	**117.0**	**82.0**	**114.3**	**6.64**	**6.10**	**6.17**
Milagro	**128.0**	**73.1**		**6.75**	**5.63**	
Montello	**115.4**	**73.3**		**6.58**	**5.90**	
Energystar	**118.6**	**76.0**		**6.62**	**5.97**	
PR39B50	**125.5**	**71.1**	**112.4**	**6.81**	**6.03**	**6.40**
Pontos	**113.3**	**80.0**	**119.2**	**6.59**	**6.07**	**6.29**
Andino	**119.1**	**70.4**		**6.54**	**5.77**	
Flavi	**130.1**	**75.8**		**6.73**	**5.90**	
n= 14	**121.2**	**74.5**		**6.64**	**5.92**	
n = 5			**114.1**			**6.33**
LSD α=5 %	**7.9**	**7.3**	**109.4**	**0.19**	**0.23**	**0.23**

Table 31: Correlation matrix for maize forage parameters of early maturity group in 2002 (significant at 0.2199)

	DM content	Elos	XF	XP	Starch content	VIVO DOM	DM yield	Starch yield	NEL
DM content									
Enzy.s.s	0.5366								
XF	-0.4477	-0.9482							
XP	-0.2608	0.1785	-0.3391						
Starch content	0.3405	0.7704	-0.8527	0.2015					
VIVO DOM	0.5361	0.9999	-0.9486	0.1787	0.7708				
DM yield	0.0966	0.0097	-0.0061	0.1126	-0.1280	0.0081			
Starch yield	0.2642	0.6970	-0.7725	0.2314	0.0432	0.6965	0.4195		
NEL	0.5211	0.9990	-0.9541	0.2190	0.7709	0.9989	0.0098	0.6973	
Energy yield	0.1716	0.4871	-0.4613	0.1989	0.2549	0.4856	0.8771	0.6998	0.4876

Table 32: Correlation matrix for maize forage parameters of early maturity group in 2003 (significant at 0.2319)

	DM content	Elos	XF	XP	Starch content	VIVOD OM	DM yield	Starch yield	NEL
DM content									
Enzy.s.s	0.7353								
XF	-0.7273	-0.9817							
XP	0.1600	0.4570	-0.5265						
Starch content	0.7779	0.9380	-0.9341	0.2925					
VIVO DOM	0.7360	-	-0.9818	0.4552	0.9386				
DM yield	0.2729	0.0869	-0.0253	-0.6347	0.1964	0.0884			
Starch yield	0.7688	0.8609	-0.8383	0.0686	0.9422	0.8619	0.5053		
NEL	0.7293	0.9996	-0.9835	0.4787	0.9341	0.9995	0.0700	0.8525	
Energy yield	0.6148	0.6169	-0.5602	-0.2390	0.6662	0.6180	0.8366	0.8707	0.6038

Table 33: Correlation matrix for maize forage parameters of mid-early maturity group in 2002 (significant at 0.2096)

	DM content	Elos	XF	XP	Starch content	VIVOD OM	DM yield	Starch yield	NEL
DM content									
Enzy.s.s	0.2178								
XF	-0.2578	-0.9716							
XP	-0.1236	0.1628	-0.3161						
Starch content	0.3257	0.8798	-0.8709	0.0771					
VIVO DOM	0.2161	0.9999	-0.9713	0.1616	0.8807				
DM yield	0.0977	0.2561	-0.1884	-0.3447	0.2236	0.2562			
Starch yield	0.2792	0.7401	-0.6930	-0.1543	0.8072	0.7409	0.7500		
NEL	0.2094	0.9990	-0.9773	0.2046	0.8764	0.9988	0.2356	0.7263	
Energy yield	0.1518	0.5586	-0.4927	-0.2238	0.4859	0.5586	0.9435	0.8942	0.5418

Table 34: Correlation matrix for maize forage parameters of mid-early maturity group in 2003 (significant at 0.1966)

	DM content	Elos	XF	XP	Starch content	VIVOD OM	DM yield	Starch yield	NEL
DM content									
Enzy.s.s	-0.0603								
XF	0.0172	-0.9464							
XP	0.0507	0.1894	-0.3652						
Starch content	0.1728	0.8791	-0.9225	0.2484					
VIVO DOM	-0.0602	0.9999	-0.9458	0.1893	0.8782				
DM yield	-0.1352	0.4108	-0.2677	-0.3358	0.2685	0.4117			
Starch yield	0.0560	0.8427	-0.7997	0.0021	0.8594	0.8425	0.7210		
NEL	-0.0578	0.9994	-0.9524	0.2214	0.8813	0.9992	0.3957	0.8364	
Energy yield)	-0.1262	0.6977	-0.5678	-0.1823	0.5448	0.6983	0.9392	0.8865	0.6860

5 Discussion

The main objective of the experiment conducted in the years 2002 and 2003 in location Berge with silage maize was to study the effect of leaf area development on dry matter yield and forage quality. During the vegetation period leaf area and leaf area index were measured by manual and LAI 2000 plant canopy analyser methods (harvest time). LAI 2000 was also used to measure light interception by plant canopy. Leaf senescence and stay green character of varieties and their effects on yield were studied. Plants were harvested to compare plant biomass production. At final harvest dry matter yield and forage quality were analysed using near infrared reflectoscopy method.

The following results were obtained from the experiments in the years 2002 and 2003.

5.1 Temperature sum (GDD)

According to figure 2 in which temperature sums (GDD) during three successive years 2002, 2003 and 2004 growing seasons of forage maize at location Berge were compared, year 2003 attained temperature sums throughout the vegetation period earliest, this was indicated at silking phase, which was earliest of all the years indicated. At GDD 800, which corresponds to silking phase, was a 4-day difference between year 2002 and 2003. Its effect was also reflected in other physiological processes like leaf area (LAI) development (figures 3 and 4). Earlier expansion in leaf area and LAI in year 2003 in both maturity groups than in years 2002 and 2004 were a result of differences in accumulated temperature. Figures 3 and 4 also indicate that highest leaf area (LAI) was attained at the time of complete leaf area expansion compared to years 2002 and 2004. The above facts seem to suggest that year 2003 had more favourable conditions for leaf area development and growth, before the onset of water deficit than in 2002 and 2004. Temperature sum played an important role in overall development process. Flowering of the maize varieties started five days earlier in 2003 than in 2002. Earlier accumulated temperature sum increased leaf development rate and earlier attainment of maximum leaf area, which led to a higher light interception rate and consequently earlier dry matter accumulation in 2003.

5.2 Leaf area and leaf number

Initial leaf development was similar in that it was slow in all varieties in both years. At about 30 days after emergence, a sharp increase in leaf area development commenced with differences in rates of leaf development in early and mid-early maturity groups becoming defined (table 12 and 13). Early maturity group attained maximum leaf area at earlier dates than mid-early group. Mid-early group had slower leaf area development, but attained higher leaf area than the early group. Increase in leaf area in all varieties was a result of increase in leaf numbers and leaf sizes within the leaf generation of individual plants. Results of measurements of leaf area in leaf generation of individual plants indicated that the largest leaf sizes lied within the middle portion of overall plant leaf generations. In most varieties, both early and mid-early group, cob leaf had the largest leaf area, or at least a leaf above or below it. Cob leaf and 2-3 leaves above and below it accounted for nearly 70 % of total plant leaf area in both maturity groups. Loss of leaves due to senescence was low in 2002 with all varieties maintaining at least 4-5 green leaves below cob leaf at harvest time. In 2003 due to water deficit in July and August most leaves below cob leaf and often times, including cob leaves were lost to drought-imposed senescence. Senescence rate was also increased from top down the leaf generations in 2003 than in 2002 because of drought. As a result in 2003 leaf area (size) and total leaf numbers of individual plants (varieties) were greatly reduced due to drought-imposed senescence. Reduction in green leaf area meant reduction in ability to intercept light which was necessary for photosynthesis and hence affecting yield and quality parameters.

Leaf area development was faster in 2003 than in both years 2002 and 2004. Leaf area of individual plants (varieties) varied from year to year as well as the leaf number. As figures 15 and 16 indicate, leaf areas and numbers in nearly all check varieties in both maturity groups were larger in year 2003 than in years 2002 and 2004, before severe drought in August 2003 set in. This seemed to indicate that the conditions for growth in year 2003 were more favourable during most of the vegetation period, especially from germination upto silking.

Water deficit set in after all the leaves were already fully expanded. Under environmental conditions of Berge with limited water supply during plant growth, high leaf areas and leaf numbers are disadvantageous to maize production for silage. The optimum range of leaf numbers (generation) under Berge conditions for both maturity groups falls between 14 and 16.

Varieties with more leaf numbers had also higher leaf areas and consequently higher leaf area indices. This, however, was not a general rule because some varieties had small individual leaf areas, which accounted for lower average leaf areas of such varieties, although they had high leaf numbers. Variety PR39H32 of early maturity group for instance had an average of 14 leaves per plant, lower than most varieties within this group, but had relatively larger leaf areas of individual leaves compared to other varieties, which accounted for high leaf area index of 4.1. On the other hand, variety Eurostar (mid-early) had 16 numbers of leaves, with leaf area index of 4.5. However other factors like leaf angle, plant height might have also determined the varying values of LAI among varieties. Comparing experimental years 2002 and 2003, leaf numbers, leaf areas and leaf sizes were greatly reduced in 2003 due to water deficit which occured in August 2003. The differences were expressed as differences in maximum total plant leaf area and total green leaf area at harvest (figures 15 and 16).

Maximum sum of leaf area per plant in early maturity check varieties ranged between 4000 and 5000 cm^2, while total leaf number was between 14 and 18 (figure 15). At harvest time, the maximum sum of leaf area was reduced to between 1500 and 2500 cm^2, total leaf number was between 5 and 8. Leaf senescence left between 9 and 12 dried leaves per plant. Check varieties with higher number of leaves lost more leaves through senescence than those with fewer leaf numbers. Check variety Pernel for instance, had total leaf number 18, lost 12 to senescence and remained with 6 green leaves at harvest, while check variety Talman with total leaf number of 14, lost 9 and had 5 green leaves at harvest.

Maximum leaf area per plant in mid-early maturity check varieties ranged between 4000 and 5000 cm^2, while the total leaf number was between 16 and 18 (figure 16). At harvest, the maximum sum of leaf area was reduced to between 1000 and 2500 cm^2 and the total leaf number to between 6 and 8. Leaf senescence left 9 – 11 dried leaves per plant. The number of senesced leaves was higher in varieties with higher total leaf numbers than in varieties with lower total leaf numbers. For instance, check varieties Sandrina and Acapulco both had total leaf numbers of 17, lost 11 to senescence and had 6 vital and green leaves each at harvest, while check variety Rivaldo and Flavi, both had total leaf numbers of 16 each, lost 9 and had 7 green and vital leaves at harvest.

In 2002, all varieties in all maturity groups maintained up to 3 and 4 green leaves above and below cob leaf at time of harvest, with cob leaf or those adjescent to it (top or below), having the largest leaf area in most varieties. Senescence was predominantly from below. However, in 2003, due to drought at harvest nearly up to the 11th leaf was dry, including cob-leaf (a majority of varieties had cob-leaves on 9th-12th leaf). As a result of drought-imposed leaf senescence, greater leaf areas and sizes were reduced in 2003 than in 2002.

5.3 Leaf senescence

In the experimental years 2002 and 2003, leaf senescence markedly differed, mainly as a result of water availability to the plants. In 2003, senescence was hastened by water deficit in mid August, which affected not only the rate at which leaves dried out, but also leaf sizes, numbers and duration of senescence. Before the onset of water deficit, all varieties in both early and mid-early maturity groups had lost averagely up to the 5th lower leaf due to senescence. Results on leaf area development showed that all varieties in both maturity groups had already attained maximum leaf area (expansion) before water deficit set in (table 3 and 4). The effect of water deficit was mainly on the grain-filling phase of corn. However, the remaining leaves began to dry out rapidly from both ends of the plant as drought intensified in mid August 2003. There was a drastic reduction in leaf number and area (also size) of individual leaves as a result of drought as compared to year 2002. A comparison between maximum leaf area per plant at harvest and total number of remaining green and vital leaves were made for both years and maturity groups. High total plant leaf area was not necessarily a result of high leaf number of a variety, but in some cases a result of larger leaf sizes (area) of individual leaves. At harvest time, total green leaf area (sum) also did not always correspond to leaf number of green leaves, but to the sizes (areas) of individual green leaves. Leaf senescence seemed to favour varieties (early and mid-early check varieties) with fewer total leaf number. The more leaves (total) a variety had, the more leaves it lost to senescence, especially during the period of extreme water deficit. Water deficit did not only hasten senescence from both ends of the plant, but also caused a shift in leaves with the largest leaf areas (sizes) from middle (cob zone), upwards, above cob zone. The last leaves to dry under extreme drought condition were 2-3 leaves above cob-leaf. The next question to ask is whether these leaves were still photosynthetically active or cosmetically green.

5.4 Stay-green characteristics and yield

Loss of green leaves to senescence reduces a plant's capability to intercept light energy that is necessary for photosynthesis. As the assimilation surface is reduced through leaf senescence, dry matter production decreases. One of the most devastating effects on silage maize production is caused by drought-imposed leaf senescence. Therefore, among the major challenges for crop improvement programmes is to develop plants that have an advantage in water-limited environments. Stay-green or delayed foliar senescence, is one of such traits in test for any advantage in yield over non stay-green. During postanthesis drought, genotypes (varieties) possessing the stay-green trait are said to maintain more photosynthetically active leaves than genotypes not possessing this trait (ROSENOW et al.1983). Expression of stay-green has been reported in cereals including *Zea mays L.* (CRAFTS-BRANDNER et al. 1984, RAJCAN & TOLLENAAR 1999 a).

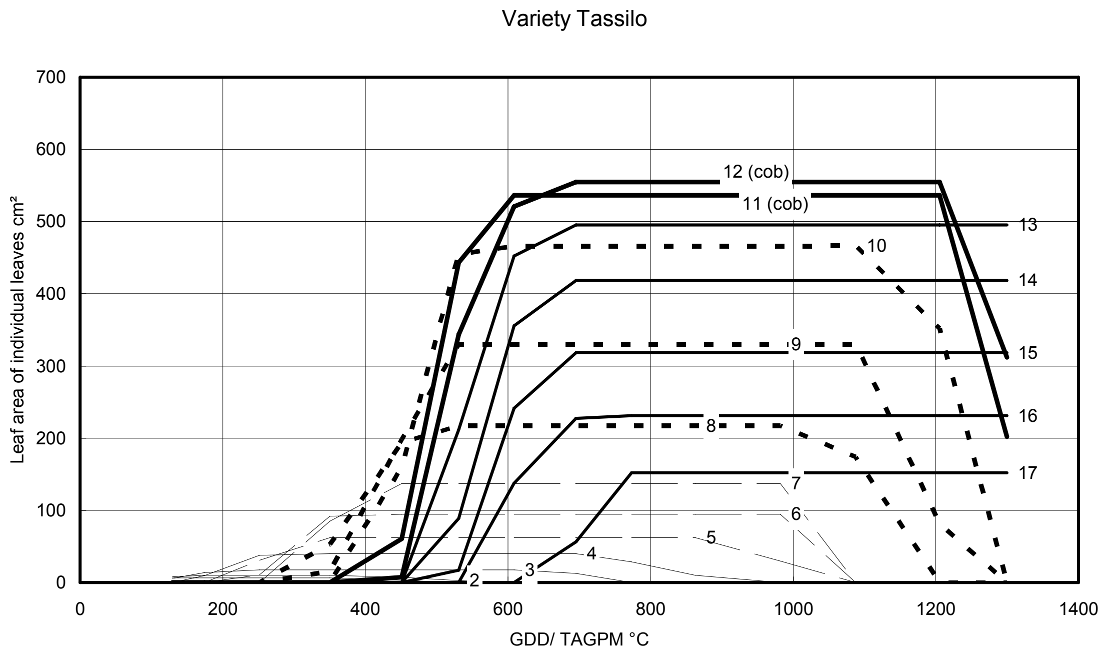
Stay-green trait of varieties tried in 2002 and 2003 was expressed as green leaf area at physiological maturity. This could also be deduced from the maximum (total) plant leaf area minus duration and rate of leaf senescence. Stay-green character was harder to distinguish from non stay-green varieties under favourable growing conditions with adequate precipitation in year 2002, than in 2003. Under growing conditions in 2002, senesced leaves of the varieties in both maturity groups tested went through normal aging and death. A narrow margin of percent green leaf area at harvest existed in 2002 within varieties of the same maturity group as well as between varieties of different maturity groups (figures 13 and 14). In 2002, all check varieties in both maturity groups maintained between 90 and 96 % of green leaf area at harvest. In year 2003 however, stay-green trait, due to water deficit were expressed in mid-early and probably in early maturity group. There were greater fluctuations in percent green leaf area at harvest within and between the maturity groups. Percent green leaf area at harvest was between 20 and 55 % in both maturity groups, far less than those of 2002 figures. In both early and mid-early maturity check varieties, those varieties which had high yield under favourable growing conditions in 2002 also indicated better yield under adverse water deficit conditions in 2003. Nearly similar patterns in decrease in yield and reduction of green leaf area at harvest were followed in both maturity groups, but in varying degrees (figures 23 and 24). High green leaf area at harvest was not necessarily accompanied with higher yield. Varieties with higher maturity numbers S 240 and S 250 (LG 3226, Rivaldo Sandrina and Flavi) maintained higher green leaf area at harvest during adverse weather conditions of water deficit (2003) than S 230 varieties (Acapulco and Topper). Within the maturity groups, there were variations in yield and green leaf area at harvest. Variety Acapulco within mid-early group (S 230), with the lowest green leaf area of the check varieties, maintained high yield, while variety Tassilo within early maturity group (S 200), indicated greater tendency to stay-green in water deficit conditions with improved yield. Variety Talman (S 210), with much reduced green leaf area at harvest maintained better yield during water deficit than other check varieties within that group, indicating yield stability under adverse weather conditions. Mid-early maturity group was preferably harvested at a much later date as compared to early maturity group, taking the advantage of wider harvest window in the former maturity group than in the latter (SCHMIDT 2002). The difference in harvest date between early and mid-early maturity groups was 8 days, 15.08 03 for early and 23.08.03 for mid-early. Earlier harvest date (3-4 days) for mid-early maturity varieties would have shown a better picture in percent green leaf area retained at harvest within and between the maturity groups (Mid-early maturity group was harvested on a much later date due to some technical faults with the harvestor). Dry matter content was higher in mid-early maturity group (mean 43.61 %) than in early maturity group (mean 39.29 %). The vegetation period was shortened in 2003 due to water limitation and high temperature, resulting in earlier harvest dates than expected.

5.5 Percentage green leaf area at harvest

Comparison between years 2002 and 2003 showed that greater green leaf area was retained in year 2002 than 2003 in both maturity groups (figures 13 and 14). Above 90 % of green leaf was retained in 2002, while only 20-55 % green leaf was retained in 2003 in both maturity groups. The great difference in green leaf area retention at harvest in both years is explained by the diverse differences in weather conditions in both experimental years, precipitation (water availability) being the greatest single factor. More precipitation was received during the 2002 vegetation period than 2003 (figure 1). Drought in August 2003 accelerated rate of leaf senescence, thereby quickly reducing green leaf area, size and leaf number. According to figures 3 and 4, the same leaf areas were attained earliest in 2003 compared to 2002 and 2004, by both early and mid-early maturity groups (only core varieties represented in the figures). The highest leaf areas were also attained in 2003 in comparison to 2002 and 2004, before intensive drought in August 2003 set in. In the absence of drought, a longer plateau of maximum and highest leaf area in years 2002 and 2004 might have resulted.

5.6 Leaf area duration

The general pattern of individual leaf development in both maturity groups was similar, varying mainly in maximum leaf area and leaf area duration. The lower leaves of the plants which emerged during the early stage of plant growth expanded to maximum leaf area between GDD 200 and 400 (figure 25), dried up at a much earlier stage than the rest of the leaves. These were mainly the first 5-6 lower leaves of the plants. Between GDD 600 and 800, all leaves had attained maximum leaf area, which also corresponded to the period of continuous stem elongation, beginning and end of tassel emergence, pollination and flowering. At the phase of silking (maximum leaf area), cob leaf had attained one of the highest leaf areas within the leaf genaration. This fell mostly between 9th and 12th leaf generation. Under normal growing conditions with sufficient precipitation, leaf generation within the cob zone (at least 2 leaves below cob leaf), cob leaf inclusive, are the last to senesce, but figure 25 below depicts leaf senescence as accelerated by water deficit. Senescence affected cobleaves, leaving only 13th, 14th and 15th leaves above cob leaf green, which had comparatively lower leaf areas than those within the cob zone. The difference between maximum leaf area (fully expanded leaves) and leaf area at harvest (green) indicate the rate at which leaf senesced, which also defined the duration or longevity of each individual leaf in GDD (not calculated). The more intense the drought, the steeper was the slope, (the faster was the rate, the shorter was the duration of leaf senescence). Figure 25 is characteristic of individual varieties in both maturity groups in year 2003 under drought conditions. Between GDD 1000°C and 1200°C was seen a great reduction in leaf area in leaves below cob leaf. Rapid reduction in leaf area above cob leaf through senescence was between GDD 1200°C and 1400°C. Grain development and kernel set were affected by rapid leaf senescence under water deficit, dry matter yield was low, dry matter content high as a result. Under favourable growing conditions of 2002, a longer plateau for maximum leaf area and a more gentle slope resulted in increased leaf area duration, higher green leaf area at harvest (functional photosynthetic apparatus), which contributed to improved dry matter yield and dry matter content.



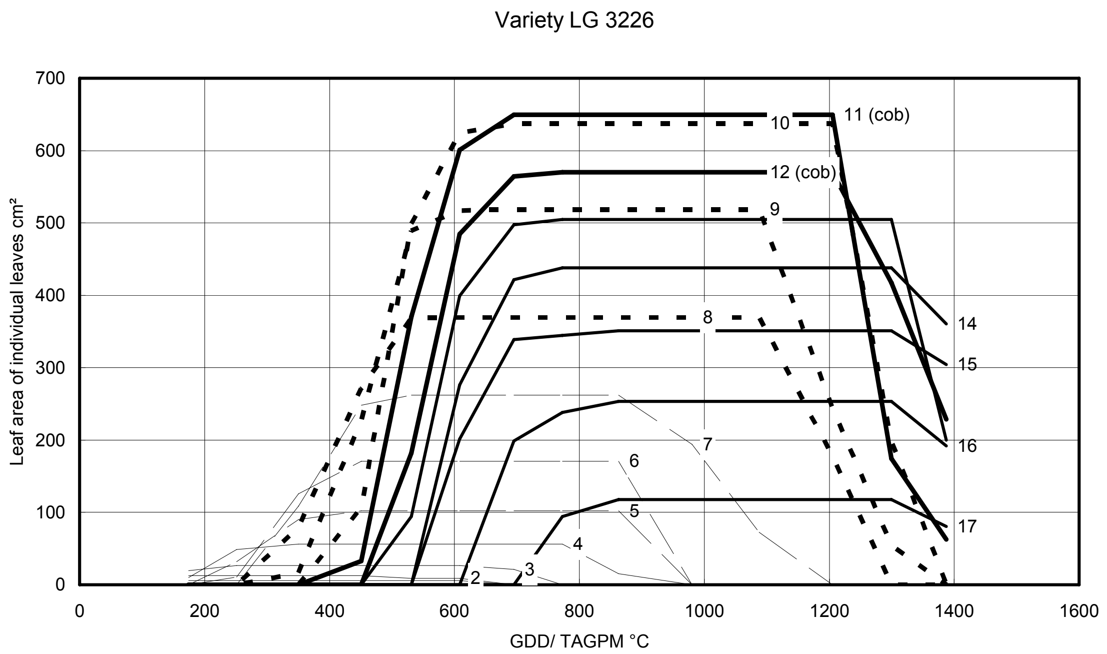


Figure 25: Leaf area development and senescense in two check varieties of early and mid-early group of forage maize having the same number of leaves in 2003 (Tassilo and LG3226)

5.7 Specific leaf area

Specific leaf area (SLA projected leaf area per dry mass) has become an important variable in comparative plant ecology because it is associated with many critical aspects of plant growth and survival. For instance SLA is often positively correlated with seedling potential relative growth rate (MULLER & GARNIER 1990, POORTER & REMKES 1990) and leaf net photosynthetic rate (FIELD & MOONEY 1986, REICH et al. 1997, SHIPLEY & LECHOWICZ 2000), it is negatively correlated with leaf life span (REICH et al. 1992) and palatability to herbivores (LUCAS & PEREIRA 1990). In the experimental years 2002 and 2003 maize varieties in both early and mid-early maturity groups showed similar trends in SLA. Individual plants had cob leaves with the largest leaf area and highest dry weight. While both leaf area and leaf dry weight decreased towards both ends of the cob leaf, SLA increased downwards below cob leaf. Leaves above cob leaf nearly maintained the same level as the cob leaf, except the last 2-3 uppermost leaves, which had higher SLA than the proceeding ones. The last leaf at apex had the lowest dry mass compared to the corresponding leaf area hence a much higher SLA than the proceeding leaves below it. Although there were fluctuating values of leaf area and leaf dry weight up and down the leaf generation, the general trend for the curve was the same in all varieties in both maturity groups, leaves below the cob leaf having higher SLA than those above cob leaf. Most cob leaves or at least 1-2 leaves above or below it registered the highest leaf dry weight. Similar results were also observed with cob leaf areas being highest or at least 2-3 leaves above and below cob leaf. The upper leaves (above cob) had higher leaf dry weight than those below the cob. Similarily, leaves above the cob had higher (larger) leaf areas than those below. SLA at plant level, except for the 2-3 upper most leaves which were relatively small in size (area) and weight that resulted in higher SLA than those below, had a similar trend. The general trend for nearly all varieties was that of increasing SLA from top downwards. Leaves above cob had lower SLA than those below. If SLA indicates 'leaf thickness', then 'leaf thickness' increases from top to bottom if the last two top-most leaves were exempted, due to their relatively small sizes (and dry mass). According to figs. 17, 18, 19 and 20, SLA was lower in 2002 in both maturity groups than in 2003 (referring only to cob leaf position), at 15 and 18 kg m^{-2} in 2002 and 2003 respectively. This result possibly agrees with REICH et al. 1992, which stated that SLA is negatively correlated with leaf life span. In 2002, leaf life span of the varieties in both maturity groups were longer, hence lower SLA than in 2003. According to table 17 the leaf area was a product of leaf dry weight and SLA, therefore SLA is an important parameter that can be used to calculate either of the parameters, when the other is known. The table also indicates that these three parameters are useful in roughly determining leaf generation of a plant in relation to cob position. When cob leaf position and leaf generation are unknown, with the three parameters in place, then cob leaf is positioned where SLA is lowest, leaf dry weight highest and leaf area largest. This result agrees with the assessment of BIRCH et al. (1999), who stated, that SLA is the likely consequence of leaf area expansion and dry matter accumulation in leaves.

5.8 Dry matter yield and dry matter content

Dry matter yield is an important trait because most production costs are incurred on a unit area basis. Improved dry matter yield often results in more efficient use of plant nutrients.

Dry matter accumulation is closely associated with leaf area development. The development of leaf area is a function of both leaf numbers and leaf size, these factors may change differently, depending on the genetic material involved and the environment in which the plants are grown. Leaf area development differed in both experimental years 2002 and 2003 due to contrasting weather conditions during the vegetation periods. Although the rate of leaf development was faster in 2003 than in 2002 between BBCH 19-65, the normal trend of leaf development after silking was interfered with by water deficiency, which also interrupted the grain filling process, hence affecting both yield and quality. Even though the maximum leaf area and leaf area index per plant were relatively higher in 2003 than in 2002 (average of 4701 cm² and 3.76 for early 4829 cm² and 3.86 for mid-early (2003), compared to 4193 cm² and 3.35 for early and 4514 cm² and 3.61 (2002), leaf area and LAI of green leaves at harvest were comparatively small in 2003 (1609 cm² and 1.29 for early and 1522 cm² and 1.22 for mid-early), 2002 (3852 cm² and 3.08 for early and 3911 cm² and 3.13). In experimental year 2003, adverse weather conditions at the research station of Berge, namely drought stress during the vegetation period, accompanied with high temperature in mid July/August, resulting in earlier than expected harvest in mid August, accounted for relatively low dry matter yield and high dry matter content compared to 2002. The average dry matter yield was 105.0 dt ha^{-1} for early and 125.4 dt ha^{-1} for mid-early maturity groups in 2003 (App. 4 and 5) as compared to 176.5 dt ha^{-1} and 181.5 dt ha^{-1} respectively, in 2002 (App. 1 and 2). There were significant differences in dry matter yield within early maturity group tested in 2002 and 2003 (13 varieties). This might have been caused by differences in soil textures of the plots in both years. The plot where early maturity group was grown in 2003 was more sandy than that of the previous year. Water retention capability was low and under condition of drought, sandy soil lost water faster than the more sandy loam. This affected the amount of water taken in by the roots, which in turn depended on other factors like root depth of individual variety, total surface area of root hairs available for water absorption. Under such conditions, individual traits of a variety were much more expressed than under normal growth conditions. There were insignificant differences within mid-early group tested in 2002 and 2003 (14 varieties). Core varieties, in 3 years trial between 2002 and 2004 (3 early and 6 mid-early varieties), also showed insignificant differences in dry matter yield between varieties within each group. However, significant differences were found in Year * Variety interaction in both maturity groups. This indicated that yearly changes in environmental conditions, apart from genotypic differences among individual varieties, played a vital role in initiating and directing the course of growth and development among the varieties, which also determined yield and forage quality. Although weather conditions at the research station for both years sharply contrasted, namely one being more favourable than the other, yet the relation of average dry matter yield and dry matter content between the maturity groups did not alter. As it was the case in year 2002, the average dry matter yield and content in year 2003 for mid-early maturity varieties were higher than those of early maturity varieties. However the average dry matter yield for year 2003 of early maturity varieties (105.0 dt ha^{-1}) and mid-early maturity varieties (125.4 dt ha^{-1}) were much lower than for year 2002: early 176.5 dt ha^{-1} and mid-early 181.5 dt ha^{-1}. The average dry matter content for year 2003 for both early (39.29 %) and mid-early (43.61 %) maturity varieties were higher than the values of year 2002 of 34.4 % and 38.2 % respectively. Significant differences were found in dry matter content in early maturity varieties tested in 2002 and 2003, but insignificant differences in mid-early varieties and core varieties. Dry matter content in both maturity groups exceeded the optimum level required at harvest of 30-32 % for early and 34-36 % for mid-early maturity group. This was a result of high temperatures during the grain filling period which hastened the process, thereby increasing the content above normal.

Dry matter yield was closely linked to leaf area index. However, LAI higher than 3.5 (the average maximum LAI for both maturity groups in 2002 by LAI 2000) was not a guarantee to improved dry matter yield or dry matter content. Year 2002 had one of the good weather conditions under which silage maize could be grown in Berge, under optimum LAI between 3-3.5. Average dry matter yield and dry matter content were higher in mid-early maturity group than in early in both years. Figs. 22 and 23 show higher green leaf area at harvest in 2002 than in 2003, which also corresponded to higher dry matter yield in 2002 than in 2003. However, within each maturity group within each year, high green leaf area did not necessarily indicate greater yield. This means that improvement in dry matter yield under water limited conditions could not be attributed to green leaf area at harvest only. Moreover, there was no confirmation as to whether the visually green leaves at harvest were actually photosynthetically active or just cosmetically green and therefore unable to photosynthezise.

The intensity and duration of drought also determined the activity and duration of leaves and their effect on dry matter yield.

5.9 Forage quality

Quality parameters of silage maize considered in the maturity groups tested were: Starch content, energy content, starch yield and energy yield. Other parameters that were analysed, beside those above included: crude fibre, crude protein, VIVO DOM, enzyme soluble organic substances.

Generally, lower starch content was obtained in 2003 than in 2002 in both maturity groups. Average starch content for all early maturity group tested in 2002 was 34.9 % compared to 27.8 % in 2003, 37.6 % in 2002 and 31.3 % in 2003 for mid-early maturity group (tables 27 and 28). Analysis of variance of varieties tested in both years in both maturity groups (13 of early and 14 of mid-early) indicated insignificant differences in starch content between varieties within each group, but significant differences between the years. Early core (varieties in 3 year trial) varieties however showed insignificant differences within the group and also between the years. The mid-early core varieties showed significant differences between the varieties within the group as well as between the years. The results for early and mid-early varieties tested in 2002 and 2003 showed that year to year differences in starch content were a result of yearly changes in environmental conditions in Berge. In this case, the differences in starch content between 2002 and 2003 were a result of contrasting relatively favourable weather condition of sufficient precipitation (737 mm) and average temperature of 10°C in 2002, compared to (342 mm) and 10°C in 2003, accompanied by drought end July and August. Poor starch fill was a result of unfavourable conditions, like high temperature. Starch content affects energy content, which is one of the determinants of forage quality.

Higher values of energy content were obtained in both maturity groups in the year 2002 than in 2003. Average energy content of early maturity group was 6.52 MJ NEL kg^{-1} (2002) and 5.87 MJ NEL kg^{-1} (2003), 6.61 and 5.95 MJ NEL kg^{-1} for mid-early maturity group in year 2002 and 2003 respectively (table 29 and 30). Analysis of variance showed insignificant differences in energy content between varieties within mid-early maturity group and mid-early core varieties. Significant differences were seen between the years. In both years, the average energy content was higher in the mid-early than in the early maturity group.

Starch yield was also affected by unfavourable weather conditions in the year 2003, as a result lower values of starch yield were obtained than in 2002 (tables 27 and 28). Average starch yield in 2002 was 61.5 dt ha^{-1} and 29.4 dt ha^{-1} in 2003, 68.3 dt ha^{-1} and 39.4 dt ha^{-1} for the mid-early maturity group in 2002 and 2003 respectively. However, insignificant differences were seen within the year among varieties of the same maturity group, while significant differences were noticed between the years. In both years, mid-early maturity varieties indicated higher starch yield than early.

Higher values of energy yield were obtained in 2002 than in 2003 in both maturity groups (tables 29 and 30). Analysis of variance showed significant differences between varieties within the early maturity group and between the years. Insignificant differences were found within varieties of the mid-early group and in core varieties of both maturity groups. In both years, the mid-early maturity group indicated a higher energy yield than the early group.

Similar results were obtained with crude fibre in both maturity groups. Crude fibre is one of the important indicators of forage structure, in addition to ADF and NDF, which affects digestibility of maize forage. Insignificant differences were found between varieties of the same group, but significant differences between the years. Core varieties of the early maturity group showed insignificant differences both within and between the years, which suggests that crude fibre was not affected by changes in environmental conditions.

According to analysis of variance for both maturity groups and core varieties, crude protein was not affected by yearly changes in environmental conditions in early maturity group and early maturity core varieties. There were insignificant differences within and between the years. Mid-early maturity group however showed insignificant differences within the group, but significant differences between the years.

In conclusion, there were significant differences in forage quality between year 2002 and 2003. The differences were a result of interaction between environment and the varieties. Under favourable environmental conditions, like in 2002, dry matter yield were high with better forage quality, however under unfavourable conditions of water limitation and high temperature as in 2003, low dry matter yield, high dry matter content resulted, with low forage quality. The results showed that crude fibre and crude protein were insiginificantly affected between the years.

Very high, positive correlation existed between enzyme soluble organic substances and vivo digestible organic matter, starch content, enzyme-soluble organic substances, netto energy for lactation in both maturity groups and in both years. Very high, but negative correlation existed between crude fibre and enzyme soluble organic substances, starch content, vivo digestible organic matter and netto energy for lactation. Crude fibre was negatively correlated with all given parameters in both years and maturity groups. Crude protein indicated between low positive to low negative correlation with other parameters in both years and maturity groups. Dry matter content of early maturity group in 2003 expressed higher correlation with other parameters than in 2002. Generally, dry matter yield and dry matter content had low correlation with other parameters given. Higher correlation were seen in all parameters of early maturity group in 2003 than in 2002, suggesting that under unfavourable weather conditions, correlation between the parameters were strongly expressed than under favourable growing conditions of 2002.

6 Conclusions

With the aim of studying the influence of leaf area development on dry matter yield and forage quality of early and mid-early maturity varieties of maize, two year experiments were conducted in 2002 and 2004 at Berge research station, belonging to the Institute of Crop Science, Faculty of Agriculture and horticulture, Humboldt-University Berlin.

Temperature sum (GDD) was accumulated from the day after sowing to the day of harvest to determine the various phases of development.

Maintaining green leaf area at harvest especially during adverse environmental conditions, like water deficit and high temperatures, was seen as an indicator of stay green trait. Comparisons were made between varieties within the groups and between the years for high green leaf areas at harvest and dry matter yield.

Since the objective of the experiment was to find out to what extent changes in leaf development during the course of plant growth and development would influence dry matter yield and forage quality, varieties were grown to full physiological maturity before harvest. Timing for optimum harvest that would make for best forage quality results was an integral part of the experiments. From the results obtained in the two years research work, including additional information on results in 2004, the following conclusions are made:

Between the varieties and years significant LAI differences existed. The maximum leaf area was reached at the phase of silking in both maturity groups. Maximum LAI lied between 2.8 and 4.6. LAI increased with increase in leaf number and leaf size during the vegetation period. LAI started to decline with onset of senescence due to aging of leaves from the lower leaf generations upwards. LAI in both maturity groups remained high in 2002 at harvest time, which also corresponded to the high green leaf area at harvest because of available water and cooler growing conditions. LAI fell sharply after silking in 2003 with a sharp reduction in leaf area and leaf number due to water deficit and heat.

Leaf area development during the vegetation periods was governed by temperature sums (GDD) for each year. The required temperature sum for each phase of development was reached earliest in 2003, which also corresponded to early attainment of higher leaf area and leaf area index at a given time in 2003 than in 2002 and 2004. Silking dates differed between the years in association with differences in temperature sums, with earliest silking in 2003, with a 4-day difference in beginning of silking dates for year 2002 and 2003. Although rainfall distribution throughout the vegetation period was lower in 2003 (average mm) than in 2002 (average mm), also with higher temperature means than 2002, higher leaf area and leaf area index were produced in both maturity groups in 2003 than in 2002 before drought. This also explains the effect of increased temperatures in accelerating rates of physiological processes in plants, including leaf area development, sometimes shortening the duration of the processes involved.

Although less water was received in 2003 than 2002 during the vegetative periods, the plants seemed to have used it more effectively during the vegetative growth, reflected in higher attainment of leaf area and leaf area index in 2003 than in 2002. This also illustrates that higher water requirement is needed during the early generative period of development than in the vegetative phase. Achieving high leaf area development alone during the vegetative period in 2003 was not enough to guarantee higher dry matter yields and good forage quality under acute water deficit during silking and post silking phases.

At the onset of water deficit in mid July of 2003, all varieties in both maturity groups had attained maximum leaf area (approximately 4300 cm^2 for early and 4800 cm^2 for mid-early core varieties) and leaf area indices of 3.3 and 3.8, respectively. Water deficit hastened senescence rates and effectively reduced green leaf area and leaf number. Using cob leaf as reference position in relation to leaf generation of the plants, in 2002, all varieties in both maturity groups maintained a minimum of 4 leaves below the cob leaf green and active at harvest. In 2003, drought-imposed senescence affected cob leaves, reduced leaf areas of those leaves above the cob leaf, with the result that green leaf area and leaf area index of varieties in both maturity groups were greatly reduced in comparison to the year 2002.

Overall vegetation period in 2003 was reduced by drought and high temperature, especially the post silking phases. Harvest dates were influenced by environmental conditions, therefore, in addition to estimation of harvest dates based on temperature sum, a combination of methods and approaches are required to combat the uncertainty of time, intensity and duration of unfavourable conditions. To determine optimum harvest time, whole plant dry matter content is normally used, which must fall within the required values for each maturity group. However, under unfavourable growing conditions, like in year 2003, of water deficit and high temperature, plant leaf generation could also be used as a check for timing harvest. It was adviseable to harvest when at least two leaf generations below the cob leaf were still green. By the time the cob leaf was also dry, dry matter content had already risen to 39-40 %. Under drought-imposed leaf senescence in 2003, dry matter content increased rapidly with increased loss of leaves to senescence. However, in locations susceptible to water deficit, selection of varieties for high leaf numbers is not adviseable, because of greater demand for water. In location Berge, varieties with leaf numbers between 14 and 16 and maximum leaf area index of 3 are recommendable. Variety FAO 750, for instance had total leaf number of 19 (Appendix 16) but in both favourable and unfavourable growing conditions of 2002 and 2003 was caught up requiring longer vegetation period (2002) and by drought (2003). Afterall varieties with high leaf numbers lost more leaves to senescence than those with fewer leaves.

Specific leaf area (SLA), an indicator of leaf thickness, was an important parameter in determining leaf generation in a plant. Leaf area is a product of leaf dry weight (g) and specific leaf area. Specific leaf area was higher in 2003 in both maturity groups than in 2002. Cob leaf positions indicated 15 $m^2 kg^{-1}$ in early and mid-early maturity groups in 2002 and 18 $m^2 kg^{-1}$ in both maturity groups in 2003. Similarily, leaf generations above and below the cob leaf showed in both maturity groups in 2002 lower values than in 2003. Leaf thickness seemed to increase more from the cob leaf downwards than upwards. Both maturity groups had similar patterns of specific leaf area in both years.

Plant biomass composition (cob, cob sheath, stem and leaf) expressed in percent of each variety varied between 2002 and 2003. Cob dry weight (%) varied inversely to stem and leaf dry weights. Higher cob dry weight (%) in 2002, which lied between 52.8 and 63.5 % in early and 52 and 59.4 % in mid-early maturity check varieties corresponded to lower stem/leaf dry weight (%). However, in 2003, higher stem/leaf dry weights resulted in lower cob dry weight of between 45.0 and 50.9 % for early and between 40.6 and 53.2 % for mid-early maturity check varieties.

Dry matter yield was positively influenced by leaf area development under favourable environmental conditions, giving higher yields in 2002, but under unfavourable environmental conditions of water limitation and high temperatures in 2003, dry matter yield was greatly reduced in all maturity groups, irrespective of how well leaves had developed during the vegetative phase. The differences in dry matter yield and dry matter content between 2002 and 2003 can be seen as the differences in the green leaf area and numbers maintained by the varieties at harvest, which resulted from availability of water and temperature levels.

Varieties within the maturity groups (check varieties) differed significantly between the years in green leaf area at harvest and dry matter yield. Varieties in both maturity groups reacted differently in relation to drought. Early check varieties had high green leaf area but lower yield or vise versa (Figure 23 and 24). This probably indicated genotypic variations among the varieties and yield potentials.

7 Literature

ACOCK, B., D. A. CHARLES-EDWARDS, D. J. FITTER, D. W. HAND, L. J. LUDWIG, J. E. WILSON and A. C. WITHERS (1978): The contribution of leaves from different levels within a tomato crop to canopy net photosynthesis: An experimental examination of two canopy models. Journal of Botany **29,** 815-827.

ANDRADE, F. H., M. E. OTEGUI and C. VEGA (2000): Intercepted radiation at flowering and kernel number in maize. Agronomy Journal **92**, 92-97.

ANDRADE, F. H., S. A. UHART and A. CIRILO (1993): Temperature affects radiation use efficiency in maize. Field Crops Research **32,** 17-25.

ASRAR, G., R. B. MYNENI and E. T. KANEMASU (1989): Estimation of plant canopy attributes from spectral reflectance measurements, in theory and applications of optical remote sensing (G. Asrar, Ed.), Wiley, New York, 252-296.

BAL, M. A., J. G. COORS and R. D. SHAVER (1997): Impact of the maturity of corn for use as silage in the diets of dairy cows on intake, digestion and milk production. Journal of Dairy Science **80** (10), 2497-2503.

BARBER, G. D, D. I. GIVENS, M. S. KRIDIS, N. W. OFFER and Y. I. MURRAI (1990): Prediction of organic matter digestibility of grass silage. Animal Feed Science Technology **28,** 115-128.

BARNETT, K. H. and R. B. PEARCE (1983): Source-sink ratio alteration and its effect on physiological parameters in maize. Crop Science **23**, 294-299.

BARTHELMES, G. and F. KRÜGER (2002): Sortenratgeber 2002/2003 Silomais Körnermais. Landesamt für Verbraucherschutz und Landwirtschaft Brandenburg.

BÄTZ, G. (1984) Empfehlungen zur weiteren Auswertung von Versuchsserien insbesondere unter Berücksichtigung der Prüfglied-Umwelt-Wechselwirkung. Feldversuchswesen **87**, 20-72.

BIRCH, C. J., G. L. HAMMER and K. G. RICKERT (1999): Dry matter accumulation and distribution in five cultivars of maize (Zea mays): relationships and procedures for use in crop modelling. Australian Journal of Research **50**, 513-527.

BIRCH, C. J., J. VOS and P. E. L. VAN DER PUTTEN (2003): Plant development and leaf area production in contrasting cultivars of maize grown in a cool temperate environment in the field. European Journal of Agronomy **2**, 173-188.

BLEIHOLDER, H., E. WEBER, T. VAN DEN BOOM, A. WITZENBERGER, H. HACK, P. LANGE-LÜDDEKE and R. STAUSS (1990): BBCH-Code – Einheitliche Codierung der phänologischen Stadien bei Kultur- und Schadpflanzen. 47. Deutsche Pflanzenschutz-

Tagung in Berlin. 1. bis 5. Oktober 1990. Mitt. Bio. Bundesanstalt Land- und Forstwirtsch., H. 266, 466. Berlin. Hamburg: Parey.

BOEDHRAM, N., T. J. ARKEBAUER and W. D. BATCHELOR (2001): Season-long characterisation of vertical distribution of leaf area in corn. Agronomy J. **93**, 1235-1242.

BOOTE, K. J. and M. TOLLENAAR (1994): Modelling genetic yield improvement. 533-565. In: Boote, K. J., J. M. Bennett, T. R. Sinclair and G. M. Paulsen (1994): Physiology and determination of crop yield. ASA – CSSA – SSSA, Madison, WI.

BORRELL, A. K. and G. L HAMMER (2000): Nitrogen dynamics and physiological basis of stay-green in sorghum. Crop Science **40**, 1295-1307.

BORRELL, A. K, G. L. HAMMER, A. C. L. DOUGLAS AND R. G. HENZELL (2000 a): Does maintaining green leaf area in sorghum improve yield under drought? I. Leaf growth and senescence. Crop Science **40**: 1026-1037.

BORRELL, A. K, G. L. HAMMER, A. C. L. DOUGLAS AND R. G. HENZELL (2000 b): Does maintaining green leaf area in sorghum improve yield under drought? II. Dry matter production and yield. Crop Science **40**, 1037-1048.

Bundessortenamt Hannover (1993a): DVP1 - Auswertung Einzelversuche. Version 3.0.

Bundessortenamt Hannover (1993b): DVP2 - Auswertung Versuchsserien. Version 4.0.

Bundessortenamt (2003): Beschreibende Sortenliste Getreide, Mais, Ölfrüchte, Leguminosen (großkörnig), Hackfrüchte (außer Kartoffeln) 2003. Deutscher Landwirtschaftsverlag GmbH.

BUNTING, E. S. (1976): Accumulated temperature and maize development in England. Journal of Agricultural Science **87**, 577-583.

ÇAKIR, R. (2004): Effect of water stress at different development stages on vegetative and reproductive growth of corn. Field Crops Research, (http://www.sciencedirect.com/science).

CHEN, J. M. and J. CIHLAR (1996): Retriving leaf area index of boreal conifer forests using landsat TM images. Remote Sensing of Environment **55** (2), 153-162.

CHEN, J. M., P. M. RICH, S. T. GOWER, J. M. NORMAN and S. PLUMBER (1997): Leaf area index of boreal forests: Theory techniques and measurements. Journal of Geophysical Research-Atmospheres **102**(D24), 29429-29443.

CHRISTENSEN, L. E., F. E. BELOW and R. H. HAGEMAN (1981): The effect of ear removal on senescence and metabolism of maize. Plant Physiology **68**, 1180-1185.

CIRILO, A. G. and F. H. ANDRADE (1994): Sowing date and maize productivity: I. Crop growth and dry matter partitioning. Crop Science **34**, 1039-1043.

CONNOR, D. J., V. O. SADRAS and A. J. HALL (1995): Canopy nitrogen distribution and the photosynthetic performance of sunflower crop during grain filling - a quantitative analysis. Oecologia Vol. **101**, 269-281.

COORS, J. G., K. A. ALBRECHT and E. J. BURES (1997): Ear-fill effects on yield and quality of silage corn. Crop Science **37**, 243-247.

COX, W. J., J. H. CHERNEY and W. D. PARADEE (1994): Foriage quality and harvest index of corn hybrids under different growing conditions. Agronomy Journal **86**, 277-282.

CRAFTS-BRANDNER, S. J., F. E. BELOW, J. E. HARPER and R. H. HAGEMAN (1984): Differential senescence of maize hybrids following ear removal whole plant. Plant Physiology **74**, 360-367.

CRAUFURD, P. Q., T. R. WHEELER, R. H. ELLIS, R. J. SUMMERFIELD and J. H. WILLIAMS (1999): Effect of temperature and water deficit on water-use efficiency, carbon isotope discrimination and specific leaf area in peanut. Crop Science **39**, 136-42.

CROSS, H. Z. and M. S. ZUBER (1972): Prediction of flowering dates in maize based on different methods of estimating thermal units. Agronomy Journal **64,** 351-355.

DALE, R. F., D. T. COELHO.and K. P. GALLO. (1980): Prediction of daily green leaf area index for corn. Agronomy Journal **72**, 999-1005.

DARBY, H. M. and J. G. LAUER (2002): Harvest date and hybrid influence on corn forage yield, quality and preservation. Agronomy Journal **94**, 559-566.

DAUGHTRY, C. S. T. and S. E. HOLLINGER (1984): Costs of measuring leaf area index of corn. Agronomy Journal **76**, 836-841.

DAYNARD, T. B. and L. W. KANNENBERG (1976): Relationships between length of the actual and effective grain filling periods and the grain yield of corn. Canadian Journal of Plant Science **56**, 237-242.

DAYNARD, T. B., J. W. TANNER and W. G. DUNCAN (1971): Duration of the grain filling period and its relation to grain yield in corn (*Zea mays L.*). Crop Science **11**, 45-48.

DEBLONDE, G. and M. PENNER (1994): Measuring leaf area index with the LI-COR LAI-2000 in pine strands. Ecology **75**, 1507-1511.

DEGENHARDT, H. (1996): NIRS – Untersuchungen zur Erfassung futterwertrelevanter Qualitätsparameter von Silomais-Sorten in einem Gerätenetzwerk. Dissertation Martin–Luther-Universität Halle-Wittenberg. Landbauforschung Völkenrode, 163-147.

DEINUM, B. (1988): Genetic and environmental variation in quality of forage maize in Europe. Netherland Journal of Science **36,** 400-403.

DEINUM, B. and J. J. BAKKER (1981): Genetic differences in digestibility of forage maize hybrids. Neth. J. Agric. Sci. **29**, 93-98.

DEINUM, B. and J. KNOPPERS (1979): The growth of maize in the cool temperate climate of the Netherlands: Effect of grain filling on production of dry matter and on chemical composition and nutritive value. Neth. J. Agric. Sci. **27**, 116-130.

DEINUM, B**.** and P. C. STRUIK (1988): Genetic variation in digestibility of forage Maize (*Zea mays L.)* and its estimation by near infrared reflectance spectroscopy (NIRS). In: Proceedings of the International Seminar on Quality of Silage Maize, Digestibility and Zootechnical Performance, Center for Agricultural Research, Gembloux, 1-20.

DUNCAN, W. G. (1971): Leaf angles, leaf area and crop photosynthesis. Crop Science **11,** 482-485.

DUNCAN, W. G., W. A. WILLIAMS and R. S. LOOMIS (1967): Tassels and the productivity of maize. Crop Science **7**, 37-39.

DWYER, L. M. and D. W. STEWART (1986): Leaf area development in field grown maize. Agronomy Journal **78,** 334-343.

DWYER, L. M., D. W. STEWART, R. I. HAMILTON and L. HOUWING (1992): Ear position and vertical distribution of leaf area in corn. Agronomy Journal **84,** 430-438.

EARL, H. J. and R. F. DAVIS (2003): Effect of drought stress on leaf and whole-canopy radiation use efficiency and yield of maize. Agronomy Journal **95**, 688-696.

EDER, J.(1993): Die neuen Sorten leisten mehr - Silomais mit höherem Kornanteil liefert eine energiereiche Silage. Bayerisches Landwirtschaftliches Wochenblatt 183 (52), 21-26.

EDER, J and B. KRÜTZFELDT (2000): Der Reife auf der Spur! Mit Temperatursummen die Pflanzenentwicklung vorhersagen. Mais **28**, 84-86.

EDER, J and W. WIDENBAUER (2003): Zuchtfortschritt nutzen. Erträge steigen jährlich um 1.5 dt/Hektar. Mais **2** (31), 44-47.

EDEY, S. N. (1977): Growing degree-days and crop production in Canada. Ottawa, Canada. Department of Agriculture. Publication 1635, 63 pp.

EDWARDS, G. E. and M. S. B. KU, (1987): The biochemistry of C_3-C_4 intermediates. In: The biochemistry of plants. Vol. 10. Photosynthesis. M. D. Hatch, N. K. Boardman (ed.), New York: Academic, 275-325.

EDMEADES, G. O. and H. R. LAFITTE (1993): Defoliation and plant density effects on maize selected for reduced plant height. Agronomy Journal **85**, 850-857.

EDWARDS, G. E. and D. A. WALKER (1983): C_3, C_4: Mechanisms, and cellular and environmental regulation, of photosynthesis. Oxford: Blackwell Sci. 542 pp.

ELINGS, A. (2000): Estimation of leaf area in tropical maize. Agronomy Journal **92**, 436-444.

EL-SHARKAWY, M. J. HESKETH and H. MURAMOTO (1965): Leaf photosynthetic rates and other growth characteristics among 26 species of *Gossypium*. Crop Sci. **5**, 173-195.

FAIREY, N. A. (1980): Hybrid maturity and the relative importance of grain and stover for the assessment of the forage potential of maize genotypes grown in marginal and non-marginal environments. Can. J. Plant Sci. **60**, 539-545.

FAIREY, N. A. (1983): Yield, quality and development of forage maize as influenced by dates of planting and harvesting. Can.J.Plant Sci.**63**, 157-168.

FELLER, U. and A. FISCHER (1994): Nitrogen metabolism in senescing leaves. Crit. Rev. Plant Science **13**, 241-273.

FIELD, C. B. and H. A. MOONEY (1986): The photosynthesis-nitrogen relationship in wild plants. In: GIVISH, T. J. (Ed.) On the economy of form and function. Cambridge University Press, Cambridge, 25-55.

GALLO, K. P. and C. S. T. DAUGHTRY (1986): Techniques for measuring intercepted and absorbed photosynthetically active radiation in corn canopies. Agronomy Journal **78**, 752-756.

GALLO, K. P., C. S. T. DAUGHTRY and C. L. WIEGAND (1993): Errors in measuring absorbed radiation and computing crop radiation use efficiency. Agronomy Journal **85,** 1222-1228

GANOE, K. H. and G. W. ROTH (1992): Kernel milkline as a harvest indicator for corn silage in Pennsylvania. Journal of Production Agriculture **5**, 519.

GEISLER, G. (1983): Ertragsphysiologie von Kulturarten des gemäßigten Klimas. Verlag Paul Parey. Berlin und Hamburg.

GIRARDIN, P. and M. TOLLENAAR (1994): Effects of intraspecific interference on maize leaf azimuth. Crop Science **34** (1), 151-155.

GOWER, S. T., C. J. KUCHARIK and J. M. NORMAN (1999): Direct and indirect estimation of leaf area index fAPAR. and net primary production of terrestrial ecosystems. Remote Sensing of Environment **70** (1), 29-51.

GOUDRIAAN, J. (1986): A simple and fast numerical method for the computation of daily totals of crop photosynthesis. Agricultural and Forest meteorology **38**, 249-254.

GROSS, F. (1986): Der Stärkegehalt in Silomais und seine Beziehungen zum Kolbenanteil und Nettoenergiegehalt. Das wirtschaftseigene Futter **32**(2), 141-152.

HACK, H., H. BLEIHOLDER, L. BUHR, U. MEIER, U. SCHNOCK-FRICKE, E. WERBER und A. WITZENBERGER (1992): Einheitliche Codierung der phänologischen Entwicklungsstadien mono und dikotyler Pflanzen – Erweiterte BBCH-Skala. Allgemein. Nachrichtenbl. Deut. Pflanzenschutzd. **44**, 265-270.

HAMMER, G. L., K. G. RICKERT and C. J. BIRCH (1998): Improved methods for predicting individual leaf area and leaf senescence in maize (Zea mays). Australian Journal of Agricultural Research **49** (2), 249-262.

HARRISON, J. H, L. JOHNSON, R. RILEY, S. XU, K. LONEY, C. W. HUNT and D. SAPIENZA (1996): Effect of harvest maturity of whole plant corn silage, on milk production and component yield and passage of corn grain and starch into faeces. Journal of dairy Science **79** (suppl.1), 149 (Abstr.).

HARTMANN, A. and H. H. GEIGER (2001): Siloreife - Restpflanze nicht vergessen! Auswirkungen unterschiedlicher Restpflanzenabreife auf Energiedichte und Verdaulichkeit. Mais **29** (2), 76-79.

HATFIELD, J. L., C. D. STANLEY and R. E. VARLSON (1976): Evaluation of an electronic foliometer to measure leaf area in corn and soybeans. Agronomy Journal **68**, 434-436.

HEIN, W. (2002): Silomaisanbau in Grenzlagen. Mit optimaler Witterung und pflanzenbaulichem Können zu hohen Trockenmasseerträgen. Mais **30** (4), 148-149.

HENZELL, R. G, R. L. BRENGMAN, D. S. FLETCHER and A. N. MCCOSKER (1992): Relationships between yield and non-senescence (stay-green) in some grain sorghum hybrids grown under terminal drought stress. p. 355-358. In: M. A. FOALE, R. G HENZELL and P. N. VANCE (ed.): Proceedings of the Second Australian Sorghum Conference, Gatton. Australian Institute of Agricultural Science, Melbourne, Occasional Publication. No. 68.

HEPTING, L. (1988): Zum Erntezeitpunkt bei Silomais. MAIS-Informationen, HARMS-Herford, 2/88.

HEPTING, L. (1992): Der Futterwert der Maissorten. Mais **20** (4), 16-19.

HEPTING, L. (1994): Maisanbau- am Anfang steht die Züchtung. Mais, **22** (1), 6-8.

HERRMANN, P. (2000) Bestimmung des Erntezeitpunktes bei Silomais auf Grundlage der Temperatursummen. Mais Information. RAGT Saaten. H.1, 5-7.

HESS, M., G. BARRALIS, H. BLEIHOLDER, L. BUHR, T. EGGERS, H. HACK and R. STAUSS (1997): Use of the extended BBCH scale general for the descriptions of the growth stages of mono- and dicotyledonous weed species. Weed Research Volume **37** (6), 433.

HURLE, K., M. LECHNER und K. KÖNIG (1996): Mais. Unkräuter. Schädlinge. Krankheiten. Verlag TH. MANN. Gelsenkirchen.

HUNT, C. W., W. KEZAR and R. VINANDE (1989): Yield, chemical composition and ruminal fermentability of corn whole plant, ear and stover as affected by maturity. J. Prod. Agric. **2**, 357-361.

IBRAHIM, M. E. and D. R. BUXTON (1981): Early vegetative growth of cotton as influenced by leaf type. Crop Science **21**, 639-647.

JACOBS, B. C. and C. J. PEARSON (1991): Potential yield of maize, determined by rates of growth and development of ears. Field Crops Research **27**, 281-298.

JONES, C. A and J. R. KINIRY (1986): CERES-Maize: A simulation model of maize growth and development. Texas A & M University Press, College Station, TE.

JONES, J. W, B. ZUR and J. M. BENNETT (1986): Interactive effects of water and nitrogen stresses on carbon and water vapour exchange of corn canopies. Agricultural and Forest Meteorology **38**, 113-126.

KEATING, B. A. and B. M. WAFULA (1992): Modelling the fully expanded area of maize leaves. Field Crops Research **29**, 163-176.

KLING, J. G., H. T. HEUBERGER, S. O. OIKEH, H. A. AKINTOYE and W. J. HORST (1996): Potential for developing nitrogen-use efficient maize for low input agriculturalsystems in the moist savanna of Africa. In: Proceedings of a sympossium on developing drought and low nitrogen tolerant maize, CIMMYT, Mexico, 490-501.

KNABE, O., R. SCHUPPENIES, K. D. ROBOWSKY, G. WEISE AND B. KNABE (1987): Nährstoffgehalt und Futterwert von Silomais. Feldwirtschaft **28, H.** 2, 71-73.

KROPFF, M. J., K. G. CASSMAN, S. PENG, R. B. MATTHEWS and T. L. SETTER (1994): Quantitative understanding of yield potential. In: Cassman, K.G. (Ed.). Breaking the yield barrier. Proceedings of Workshop on rice yield potential in favourable environments. IRRI, Los Banos, Philippines, MIP, 1994–1995. Maize improvement program. Archival Report. International Institute of Tropical Agriculture, Ibadan, Nigeria, 21-38.

KÖHN, W. (2002): Versuchsführer 2002 Standort Berge. Institut für Pflanzenbauwissenschaften. Landwirtschaftlich-Gärtnerische Fakultät der Humboldt-Univ. Berlin. 46 pp..

KVET, J.,J. P. ONDOK, J. NECAS and P. G. JARVIS (1971): Methods of growth analysis. In: Z. Sestak, J. Catsky and P G Jarvis (ed.): Plant photosynthetic production. Manual of methods. Dr. W. Junk N. V. Publishers. The Hague, pp. 343-391.

LAFARGE, T. A and G. L. HAMMER (2002): Predicting plant leaf area production: shoot assimilate accumulation and partitioning and leaf area ratio are stable for a wide range of Sorghum population densities. Field Crops Research **77** (2-3):137-151.

LAFITTE, H. R and G. O. EDMEADES (1997): Temperature effects on radiation use and bio mass partitioning in diverse tropical maize cultivars. Field Crops Research **49** (2-3), 231-247.

LAFITTE, H. R., G. O. EDMEADES and E. C. JOHNSON (1997): Temperature responses of tropical maize cultivars selected for broad adaptation. Field Crops Research **49** (2-3), 215-229.

LI-COR (1992): LAI-2000 Plant canopy analyser instruction manual.

LINDQUIST, J. L., T. J. ARKEBAUER, D. T. WALTERS, K. G. CASSMAN AND A. DOBERMANN (2005): Maize radiation use efficiency under optimal growth conditions. Agronomy Journal **97**, 72-78

LIZASO, J. I., W. D. BATCHELOR and S. S. ADAMS (2001): Alternate approach to improve kernel number calculation. In: CERES-Maize. Trans. ASAE 44, 1011-1018.

LOOMIS, R. S. and W. A. WILLIAMS (1969): Productivity and the morphology of crop stands: Patterns with leaves. 27-51. In: D. Eastin et al. (ed.). Physiological aspects of crop yield ASA and CSSA. Madison, WI..

LOOMIS, R. S., W. A. WILLIAMS, W. G. DUNCAN, A. DOVRAT and A. F. NUNEZ (1968): Quantitative descriptions of foliage display and light absorption in field communities of corn plants. Crop Sci.**8**, 352-356.

LUCAS, P. W. and B. PEREIRA (1990): Estimation of the fracture toughness of leaves. Functional Ecology 4, 819-822.

LÜTKE ENTRUP, N., O. ONNEN and B. TEICHGRÄBER (1996): Qualitätsmanagementsysteme und Ökobilanzen in der Landwirtschaft. Forschungsbericht Nr. 4 des Fachbereichs Agrarwirtschaft der Universität-GH Paderborn in Soest, 110 pp.

LÜTKE ENTRUP, N., O. ONNEN and B. TEICHGRÄBER (1998): Zukunftsfähige Landwirtschaft. Intergrierter Landbau in Deutschland und Europa. Studie zur Entwicklung und den perspektiven. Hrsg.: Födergemeinschaft Intergrierter Pflanzenbau e.V., Heft 14, Bonn, 295 pp.

MADAKADZE, I. C., B. E. COULMAN, P. PETERSON, K. A. STEWART, R. SAMSON and D. L. SMITH (1998): Leaf area, light interception and yield among switchgrass populations in a short-season area. Crop Science **38**, 827-834.

MADDONNI, G. A., M. CHEUE, J. L. DRONET and B. ANDRIEU (2001 a): Light interception of contrasting azimuth canopies under square and rectangular plant spatial distributions: simulations and crop measurements. Field Crops Research **70** (1), 1-13.

MADDONNI, G. A and M. E. OTEGUI (1996): Leaf area, light interception and crop development in maize Field Crops. Research **48,** 81-87.

MADDONNI, G. A., M. E. OTEGUI, B. ANDRIEU, M. CHELLE and J. J. CASAL (2002): Maize leaves turn away from neighbours. Plant Physiology **130**, 1181-1189.

MADDONNI, G. A., M. E. OTEGUI and A. G. CIRILO (2001 b): Plant population density, row spacing and hybrid effects on maize canopy architecture and light attenuation. Field Crops Research **71** (3), 183-193.

MAHALAKSHMI, V. and R. BIDINGER (2002): Evaluation of stay-green sorghum germplasm lines at ICRISAT. Crop Science **42**, 965-974.

MAHANNA, B. (1995): Lessons learned (and questions raised) from feeding the 1993 and 1994 corn crops. Page 175. In: Proc. Four-state Appl. Nutr. Manage. Conf. La Crosse, WI. Univ. Wisconsin Coop. Ext. Madison.

MAINKA, C. (1990): Futterbewertung von Silomais mit der Nah-Infrarot Reflections-Spectroskopie (NIRS). Landbauforsch. Völkenrode, Sonderheft 119, 1-96.

MAJOR, D. J., B. W. BEASLEY and R. I. HAMILTON (1991): Effect of maize maturity on radiation use efficiency. Agronomy Journal **83**, 895-903.

MARCELIS, L. F. M., E. HEUVELINK and J. GOUDRIAAN (1998): Modelling biomass production and yield of horticultural crops: a rewiew. Scientia Horticulturae **74** (1-2), 83-111.

MARUM, A. H. and P. AASTVEIT (1990): The precision of the Tilley and Terry method compared to the NIRS method in estimating digestibility in breeding programs. In: Proceedings of the 3 rd International Conference on Near Infrared Spectroscopy, 566-569.

MATTHEWS, R. B., D. HARRIS, J. H. WILLIAMS and R. C. NAGESWARA RAO (1988): The physiological bases for yield differences between four genotypes of groundnut (*Arachis hypogaea*) in response to drought. II. Solar radiation interception and leaf movement. Expl. Agric. **24**, 203-213.

MCKEE, G. W. (1964): A coefficient for computing leaf area index in hybrid corn. Agronomy Journal **56**, 240-241.

MCMASTER, G. S. and W. W. WILHELM (1997): Growing degree-days: one equation, two interpretations. Agricultural and Forest Meteorology **87** (4), 291-300.

McMichael, B. L., W. R. Jordan, J. E. Quisenberry and R. E. Dilbeck (1984): Leaf production and Growth Rates of Exotic Cottons. Agronomy Journal **76**, 901-905.

Montgomery, E. G. (1911): Correlation studies in corn. 24th Annual Report, Agricultural Experiment Station of Nebraska, 109-159.

Moreno-Gonzalez, J., I. Martinez, I. Brichette, A. Lopez and P. Castro (2000): Breeding potenzial of European flint and U.S. Corn Belt dent maize populations for forage use. Crop Science **40**, 1588-1595.

Muchow, R. C. (1989): Comparative productivity of maize, sorghum and pearl millet in a semi-arid tropical environment. II. Effects of water deficits. Fields Crops Research **20**, 191-205.

Muchow, R. C. (1990): Effect of high temperature on grain growth in field grown maize. Field Crops Research **23**, 145-158.

Muchow, R. C. and R. Davis (1988): Effect of nitrogen supply on the comparative productivity of maize and sorghum in a semi-arid tropical enviroment. II. Radiation interception and biomass accumulation. Field Crops Research **18**, 17-30.

Muchow, R. C. and T. R. Sinclair (1994): Nitrogen response of leaf photosynthesis and canopy radiation use efficiency in field-grown maize and sorghum. Crop Science **34**, 721-727.

Muchow, R. C., T. R. Sinclair and J. M. Bennett (1990): Temperature and solar radiation effects on potential maize yield across locations. Agronomy Journal **82**, 338-343.

Mughogho, L. K. and S. Pande (1984): Charcoal rot of sorghum. In L. K. Mughogho (ed.) Sorghum root and stalk rots: A critical review. Proc. Consult. Group discussion on research needs and strategies for control of sorghum root and stalk Rot diseases, Bellagio, Italy. 27 Nov.–2 Dec. 1983. ICRISAT, Patancheru, A.P., India. 11–24.

Muller, B. and E. Garnier (1990): Components of relative growth rate and sensitivity to nitrogen availability in annual and perennial species of Bromus. Oecologia **84** 513-518.

Neild, R. E. (1982): Temperature and rainfall influences on the phenology and yield of grain sorghum and maize:a comparison. Agricultural Meteorology **27**, 79-88.

NIRS 2 Version 3.00 (1992): Routine operation and calibration software for near infrared instruments. Infrasoft International.

Nooden, L. D. (1988 a): The phenomena of senescence and aging. In: Nooden, L. D., A. C. Leopold (eds.): Senescence and Aging in Plants. Academic Press, San Diego. 1-50.

NOODEN, L. D. (1988 b): Whole plant senescence. In: Nooden, L. D., A. C. Leopold (eds.): Senescence and Aging in Plants. Academic Press, San Diego, 391-437.

NORMAN, J. M. (1978): Modeling the complete crop canopy. 248-277. In: B. J Barfield and J. F. Gerber (ed.) Modification of the aerial enviroment of crops. ASAE, St. Joseph, MI.

OIKEH, S., J. G. KLING, W. J. HORST and V. O. CHUDE (1996): Yield and N-use efficiency of five tropical maize genotypes under different N levels in the moist savanna of Nigeria. In: Ransom, J.K., Palmer, A.F.E., Zambezi, B.T., Mduruma, Z.O., Waddington, S.R., Pixley, K.V., Jewell, D.C. (Eds.), Proceedings of the 5th Eastern, Southern Africa Regional Maize Conference. Arusha, Tanzania, 163–167.

OTEGUI, M. E. and F. H. ANDRADE (2000): New relationships between light interception, ear growth and kernel set in maize. In: Westgate, M. E., Boote, K. J. (Eds.), Physiology and Modeling of kernel set in maize. CSSA Special Publications No. 29, CSSA-ASA, Madison, WI, 89-102.

OTEGUI, M. E. and F. H. ANDRADE (2000): New relationships between light interception, ear growth and kernel set in maize. In: Westgate, M. E., Boote, K. J. (Eds.), Physiology and Modeling of kernel set in maize. CSSA Special Publications No. 29, CSSA-ASA, Madison, WI, 89-102.

PAN, W. L., J. J. CAMBERETO, W. A. JACKSON and R. H. MOLL (1986): Utilization of previously accumulated and concurrently absorbed nitrogen during reproductive growth in maize. Plant Physiology **82**, 247-253.

PATTEY, E. P., P. ROCHETTE, R. L. DESJARDINS and P. A. DUBE (1991): Estimation of net CO_2 assimilation rate of a maize (*Zea mays L*) canopy from leaf chamber measurements. Agricultural and Forest Meteorology **55**, 37-57.

PAUL, C., C. MAINKA and J. MÜLLER (1992): Möglichkeiten der NIRS-Technik bei Silomais. Mais **20** (4), 20-22.

PEPPER, G. E., R. B. PEARCE and J. J. MOCK (1977): Leaf orientation and yield of maize. Crop Science **17**, 883-886.

PICKERT, J., F. HERTWIG and R. SCHUPPENIES (2001): Sichere Vorhersage der optimalen Erntezeit bei Silomais. Neue Landwirtschaft **8**, 34-36.

POORTER, H. and J. R. EVANS (1998): Photosynthetic nitrogen-use efficiency of species that differ inherently in specific leaf area. Oecologia Vol. **116,** 26-37.

POORTER, H. and C. REMKES (1990): Leaf area ratio and net assimilation rate of 24 wild species differing in relative growth rate. Oecologia Vol. **83**, 553–559.

RAJCAN, I. and M. TOLLENAAR (1999 a): Source : sink ratio and leaf senescence in maize: I. Dry matter accumulation and partitioning during grain filling. Field Crops Research **60** (3):245-253.

RAJCAN, I. and M. TOLLENAAR (1999 b): Source-sink-ratio and leaf senescence in maize: I. Dry matter accumulation and partitioning during grain filling. II Nitrogen metabolism during grain filling. Field Crops Research **60**, 255-265.

RATH, J., A. HERRMANN, A. KORNHER and F. HÖPPNER (2002): Den Erntetermin von Silomais vorhersagen? Forschungsprojekt "Regionale Erntezeitprognose Silomais". Mais **30** (4), 144-147.

REICH, P. B., M. B. WALTERS and D. S. ELLSWORTH (1992): Leaf life-span in relation to leaf, plant and stand characteristics among diverse ecosystems. Ecological Monographs 62, 365-392.

REICH, P. B., M. B. WALTERS and D. S. ELLSWORTH (1997): From tropics to tundra: global convergence in plant functioning. Proceedinggs of the National Academic of Science, USA **94**, 13730-13734.

ROBERTSON, M. J. (1994): Relationship between internode elongation, plant height and leaf appearance in maize. Field Crops Research **38** (3), 135-145.

ROSENOW, D. T. and L. E. CLARK (1981): Drought tolerance in sorghum. In: Loden H. D., Wilkinson D. (Eds.). Proceedings of the 36th annual corn and sorghum industry research conference, 18-31.

ROSENOW, D. T., J. E. QUISENBERRY, C. W. WENDT, L. E. CLARK (1983): Drought tolerant sorghum and cotton germplasm. Agricultural Water Management **7**, 207-222.

ROSENTHAL, W. D., G. F. ARKIN and T. A. HOWELL (1985): Transmitted and absorbed photosynthetically active radiation in grain sorghum. Agrononomy Journal **77**, 841-845.

RUSSELL, G., P. G. JARVIS and J. L. MONTEITH (1989): Absorption of radiation by canopies and stand growth. In: Plant Canopies: Their Growth, Form and Function (G, Russell, B, Marshall and P. G. Jarvis, Eds.), Cambridge Univ. Press, Cambridge, 22-36.

SCHMALER, K., U. KRÜGER and H. RICHERT (2003):Ertrag und Qualität von Silomais in Abhängigkeit vom Wasserangebot. (Yield and quality of silage corn depending on water supply). Archives of Agronomy and Soil Science **49**, 357-374.

SCHMALER, K. and K. RICHTER (2002): Einfluss verschiedener Verfahren des Einsatzes von Zusatzwasser auf Ertrag und Qualität von Silomais. Ergebnisreport 2001/2002, 55-62.

SCHMIDT, W. (2002): Die Reifeproblematik bei Silomais und deren Bedeutung für die Sortenbewertung. Pflanzenbautagung, Gondelsheim/Einbeck 30.10 und 26.11.2002 KWS SAAT AG.

SCHUPPENIES, R. (1989): Temperaturansprüche für die Ausreife von Silomais. Feldwirtschaft **30**, 66-67.

SCHUPPENIES, R. and G. WATZKE (1985): Reifegruppenwahl in Abhängigkeit von den klimatischen Bedingungen und Einfluss der Reifegruppe bzw. Sorte auf die Qualität von Silomais. Feldwirtschaft **26**, 140-142.

ŠESTÁK, Z., J. ČATSKÝ and G. JARVIS (1971): Plant photosynthetic production. Manual of methods. Dr. W. Junk N. V. Publishers. The Hague. 800 pp.

SHENK, J. S. and M. O. WESTERHAUS (1994): The application of near-infrared reflectance spectroscopy (NIRS) to forage analysis. 406-449. In: G. C. Fahey Jr. (ed.) Forage quality, evaluation. and utilisation. ASA. CSSA. and SSSA. Madison. WI..

SHIPLEY, B. and M. LECHOWICZ (2000): The functional co-ordination of leaf morphology, nitrogen concentration and gas exchange in 40 wetland species. Ecoscience **7**, 183-194.

SHIPLEY, B. and T. T. VU (2002): Dry matter content as a measure of dry matter concentration in plants and their parts. New Phytologist **153** (2), 359.

SINCLAIR, T. R. and R. C. MUCHOW (1999): Radiation use efficiency. Adv. Agronomy **65**, 215-265.

SIVAKUMAR, M. V. K. and S. M. VIRMANI (1984): Crop productivity in relation to interception of photosynthetically active radiation. Agricultural and Forestry Meteorology **31**, 131-241.

SMITH, H. (2000): Phytochromes and light signal perception by plants - an emerging synthesis. Nature 407, 585-591.

SPANNER, M. A., L. L. PIERCE, D. L. PETERSON and S. W. RUNNING (1990): Remote-Sensing of Temperate Coniferous Forest Leaf Area Index - The Influence of Canopy Closure, understory Vegetation and Background Reflectance. International Journal of Remote Sensing **11**(1), 95-111.

SPANNER, M. A., L. JOHNSON, J. MILLER, R. MCCREIGHT, J. FREEMANTLE, J. RUNYON, P. GONG (1994): Remote sensing of seasonal leaf area index across the Oregon transection. Ecological Applications **4** (2), 258-271.

Statistisches Jahrbuch über Ernährung, Landwirtschaft und Forsten der Bundesrepuplik Deutschland 2004. Landwirtschaftsverlag GmbH Münster-Hiltrup.

STEINHÖFEL, O. (2000): Gesamttrockenmasse richtig bewerten. Objektive Prognose des optimalen Reifezustandes bei Silomais. Mais **28** (3), 122-124.

STEWART, D. W., C. COSTA, L. M. DWYER, D. L. SMITH, R. I. HAMILTON and B. I. MA (2003): Canopy structure, light interception and photosynthesis in maize. Agronomy Journal **95**, 1465-1474.

STEWART, D. W. and L. M. DWYER (1993): Mathematical characterization of maize canopies. Agric. For. Meteorol. **66**, 247–265.

STEWART, D. W. and L. M. DWYER (1994): A model of expansion and senescence of individual leaves of field-grown maize (Zea mays L.). Canadian Journal of Plant Science **74**, 37-42.

STICKSEL, E., F.-X. MAIDL, A. LUDWIG and G. FISCHBECK (1996): Die Ertragsbildung landwirtschaftlicher Kulturpflanzen in Abhängigkeit von der nutzbaren Feldkapazität bei differenzierter Stickstoffdüngung in Trockenjahren. Die Bodenkultur **47**, H. 3., 163-172.

STONE, P. J., D. R. WILSON, J. B. REID and G. N. GILLESPIE (2001): Water deficit effects on sweet corn. I. Water use, radiation use efficiency, growth and yield. Australian Journal of Agricultural Research **52**, 103-113.

TANAKA, A. and J. YAMAGUCHI (1972): Dry matter production, yield components and grain yield of the maize plant. J. Fac. Agric. Hokkaido Univ. **57**, 71 132.

TARDIEU, F., C. GRANIER and B. MULLER (1999): Modelling leaf expansion in a fluctuating environment. Are changes in specific leaf area a consequence of changes in expansion rate? New Phytologist **143** (1), 33-43.

TAYLOR, S. E. (1975): Optimal leaf form. 73-86. In: D.M.Gates and R.B.Schmen (ed.) Perspectives of biophysical ecology. Springer-Verlag, Heidelberg.

TETIO-KAGHO, F. and F. P. GARDNER (1988 a): Responses of maize to plant population density. I. Canopy development, light relationships and vegetative growth. Agronomy Journal **80**, 930-935.

TETIO-KAGHO, F. and F. P. GARDNER (1988 b): Responses of maize to plant population density. II. Reproductive development, yield and yield adjustments. Agronomy Journal **80**, 935-940.

THOMAS, H. and C. J. HORWARTH (2000): Five ways to stay-green. Journal of Experimental Botany **51**, 329-337.

THOMAS, H. and C. M. SMART (1993): Crops that stay-green. Annals of Applied Biology **123**, 193-219.

TILLMAN, P. (2002): Qualitätsuntersuchung an Maissilage. Anwendung der NIRS-Methode im Netzwerk des VDLUFA. MAIS 1, 30-31.

TOLER, J. E., E. C. MURDOCK, G. S. STAPLETON, S. U. WALLACE (1999): Corn leaf orientation effects on light interception, intraspecific competition and grain yields. Journal of Production Agriculture **12** (3), 396-399.

TOLLENAAR, M. (1977): Sink-source relationships during reproductive development in maize: A review. Maydica **22**, 49-75.

TOLLENAAR, M. (1989 a): Response of dry matter accumulation in maize to temperature. I. Dry matter partitioning. Crop Science **29**, 1239-1246.

TOLLENAAR, M. (1989 b): Response of dry matter accumulation in maize to temperature. II. Leaf photosynthesis. Crop Science **29**, 1275-1279.

TOLLENAAR, M. and A. AGUILERA (1992): Radiation use efficiency of an old and new maize hybrid. Agronomy Journal **84**, 536-541.

TOLLENAAR, M. and T. W. BRUULSEMA (1988): Efficiency of maize dry matter production during periods of complete leaf area expansion. Agronomy Journal **80**, 580-585.

TOLLENNAAR, M. and T. B. DAYNARD (1982): Effect of source-sink ratio on dry matter accumulation and leaf senescence of maize. Canadian Journal of Plant Science **62**, 855-860.

TOLLENAAR, M. and R. B. HUNTER (1983): A photoperiod and temperature sensitive period for leaf number of maize. Crop Science **23**, 457-460.

TOLLENAAR, M., T. B. DAYNARD and R. B. HUNTER (1979): The effect of temperature on rate of leaf appearance on flowering date in maize. Crop Science **19,** 363-366.

TOLLEY-HENRY, L., C. D. RAPER JR. and T. C. GRANATO (1988): Cyclic variations in nitrogen uptake rate of soyabean plants: Effects of external nitrate concentration. Journal of Experimental Botany **39**, 613-622.

VALENTINUZ, O. R. and M. TOLLENAAR (2004): Vertical profile of leaf senescence during the grain-filling period in older and newer Maize hybrids. Crop Science **44**, 827-834.

VAN OOSTEROM, E. J., R. JAYACHANDRAN and F. R. BINDINGER (1996): Diallel analysis of the stay-green trait and its components in sorghiúm. Crop Science **36**, 549-555.

VOLKERS, K. C., M. WACHENDORF, R. LOGES, N. J. JOVANOVIC and F. TAUBE (2003): Prediction of the quality of forage maize by near-infrared reflectance spectroscopy. Animal Feed Science and Technology **109** (1-4), 183-194.

WADA, Y., K. MIURA and K. WATANABE (1993): Effect of source-to-sink ratio on carbohydrate production and senescence of rice flag leaves during the ripening period. Japanese Journal of Crop Science **62**, 547-553.

WATSON, D. J. (1947): Comparative physiological studies on the growth of field crops. I. Variation in net assimilation rate and leaf area between species and varieties and within and between years. Ann. Bot. **11**, 41-76.

WANG, J. Y. (1960): A critique of heat unit approach to plant response studies. Ecology **41**, 85-790.

WANG, H. S. (2001):Einfluss von Blattstellung und Bestandesdichte auf Ertrag, Qualität und Lichtaufnahme bei Silomaissorten verschiedenen Wuchstyps. Diss. Humboldt-Univ. Berlin. 115 pp..

WEAVER, D. E., C. E. COPPOCK, G. B. LAKE and R. W. EVERETT (1978): Effect of maturation on composition and in vitro dry matter digestibility of corn plant parts. Journal of Dairy Science. **61**, 1782-1788.

WEBER, E. and H. BLEIHOLDER (1990): Erläuterungen zu den BBCH–Codes für die Entwicklungsstadien von Mais, Raps, Faba-Bohne, Sonnenblume und Erbse. Gesunde Pflanzen **42**, 308-321.

WEIßBACH, F., S. KUHLA and L. SCHMIDT (1996a): Schätzung der umsetzbaren Energie von Grundfutter mittels einer Cellulase-Methode. Proc. Soc. Nutr. Physiol. **5**, 115.

WEIßBACH, F., L. SCHMIDT and S. KUHLA (1996b): Vereinfachtes Verfahren zur Berechnung der NEL aus der umsetzbaren Energie. Proc. Soc. Nutr. Physiol. **5**, 117.

WESTGATE, M. E., F. FORCELLA, D. C. REICOSKY and J. SOMSEN (1997): Rapid canopy closure for maize production in the northern US corn belt: radiation-use efficiency and grain yield. Field Crops Research **49** (2-3), 249-258.

WIERSMA, D. W., P. R. CARTE, K. A. ALBRECHT and J. G. COORS (1993): Kernel milkline stage and corn forage yield, quality and dry matter content. Journal of Production Agriculture **6**, 94-99.

WILSON, P. J, K. THOMPSON and J. G. HODGSON (1999): Specific leaf area and dry matter content as alternative predictors of plant strategies. New Phytologist **143** (1), 155.

WOLFE, D. W., D. W. HENDERSON, T. C. HSIAO and A. ALVINO (1988 a): Interactive water and nitrogen effects on senescence of maize. I. Leaf area duration. nitrogen distribution and yield.Agronomy Journal **80**, 859-864.

WOLFE, D. W., D. W. HENDERSON, T. C. HSIAO and A. ALVINO (1988 b): Interactive water and nitrogen effects on senescence of maize. II. Photosynthetic decline and longevity of individual leaves. Agronomy Journal **80**, 865-870.

WOODMAN, J. N. (1971): Variation of net photosynthesis within the crown of a large forest-grown conifer. Photosynthetica **5**, 50-54.

WULDER, M. A. (1998): Optical remote sensing techniques for the assessment of forest inventory and biophysical stand parameters. Progress in physical Geography **22** (4), 449-476.

ZADOKS, J. C., T. T. CHANG and C. F. KONZAK (1974): A decimal code for the growth stages of cereals. Weed Research **14**, 415-421.

ZSCHEISCHLER, J., M. ESTLER, W. STAUDACHER, F. GROSS, G. BURGSTALLER, T. RECHMANN (1990): Handbuch Mais. Umweltgerechter Anbau Wirtschaftliche Verwertung. DLG-Verlag Frankfurt (Main). BLV Verlagsgesellschaft München. Landwirtschaftsverlag Münster-Hiltrup. Österreichischer Agrarverlag Wien, BUGRA SUISSE Wabern-Bern. pages 108-109.

Appendices

Silage maize, early varieties
year 2002

N

47 m

1	4	20	7
2	17	3	1
3	19	10	13
4	2	7	20
5	18	14	15
6	1	2	17
7	15	12	14
8	3	6	18
9	16	4	3
10	6	15	8
11	20	16	9
12	7	1	5
13	5	9	10
14	8	17	6
15	10	13	11
16	14	5	2
17	12	19	16
18	9	11	4
19	13	18	12
20	11	8	19
r_1	**r_2**	**r_3**	**r_4**

60 m

127 m

10 m 10 m 10 m 10 m

Figure A1: Block design with four replications (early varieties, year 2002)

Silage maize , mid-early varieties
year 2002

N

47 m

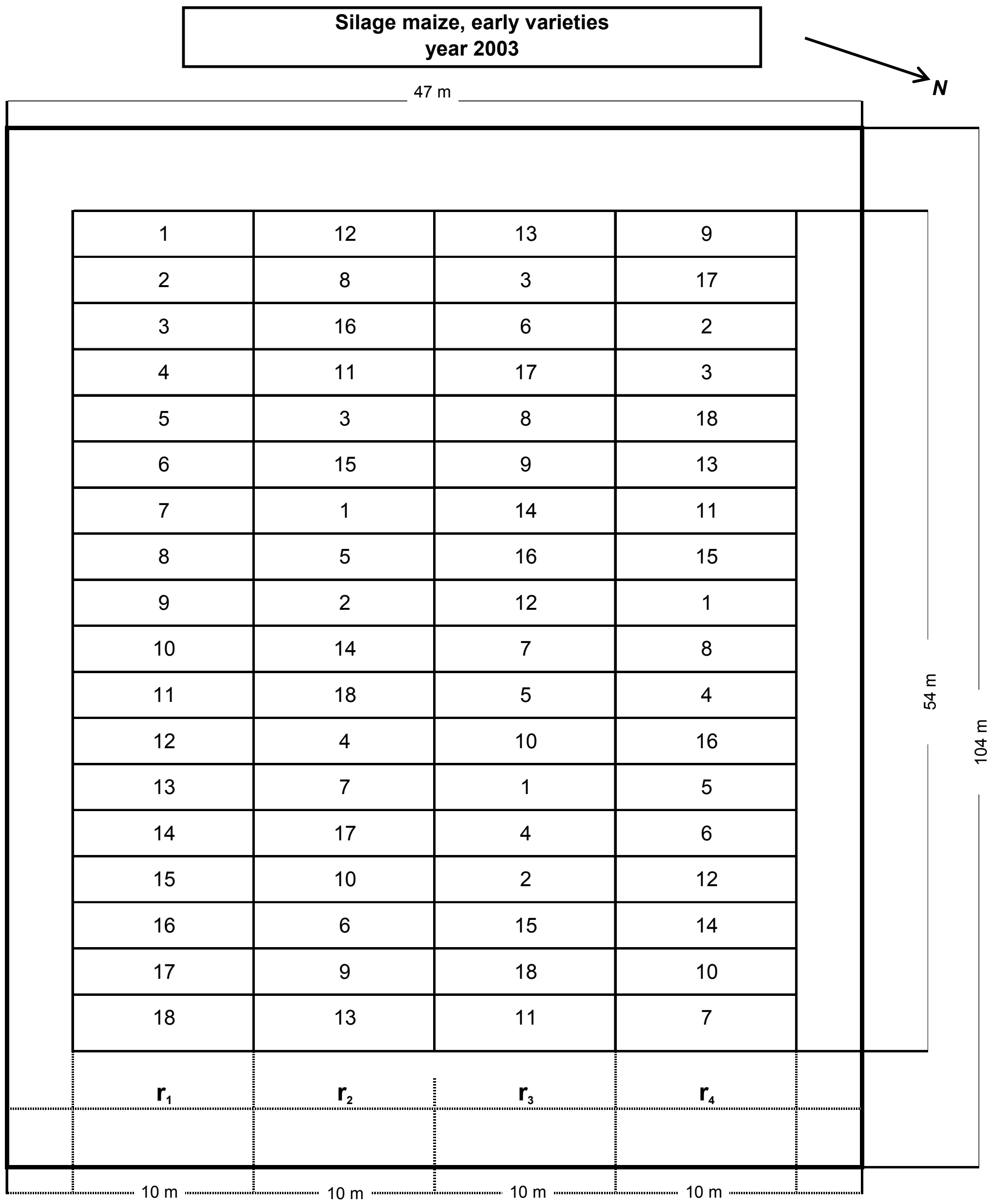
5	1	15	22
18	8	2	21
12	10	16	20
13	17	8	19
1	3	21	18
21	12	1	17
15	11	9	16
4	21	13	15
9	7	10	14
8	2	4	13
19	20	7	12
3	6	14	11
16	19	12	10
17	15	20	9
22	18	5	8
10	4	3	7
2	14	19	6
6	13	22	5
14	5	18	4
11	9	6	3
20	16	11	2
7	22	17	1
r_4	**r_3**	**r_2**	**r_1**
10 m	10 m	10 m	10 m

66 m

127 m

3 m

Figure A2: Block design with four replications (mid-early varieties, year 2002)



r_1	r_2	r_3	r_4
1	12	13	9
2	8	3	17
3	16	6	2
4	11	17	3
5	3	8	18
6	15	9	13
7	1	14	11
8	5	16	15
9	2	12	1
10	14	7	8
11	18	5	4
12	4	10	16
13	7	1	5
14	17	4	6
15	10	2	12
16	6	15	14
17	9	18	10
18	13	11	7

Figure A3: Block design with four replications (early varieties, year 2003)

Silage maize, mid-early varieties
year 2003

N

47 m

1	9	18	10
2	17	13	7
3	24	23	21
4	15	16	6
5	25	17	14
6	10	19	15
7	1	11	2
8	4	24	1
9	14	8	16
10	20	12	9
11	6	3	17
12	23	9	18
13	7	25	11
14	19	22	20
15	12	4	24
16	18	5	3
17	8	1	23
18	21	20	8
19	3	15	4
20	5	21	12
21	2	10	25
22	13	6	5
23	11	2	19
24	22	14	13
25	16	7	22
r_1	**r_2**	**r_3**	**r_4**
10 m	10 m	10 m	10 m

75 m

104 m

Figure A4: Block design with four replications (mid-early varieties, year 2003)

Table A1: Yield and quality parameters of silage maize of maturity group early in regional variety trial of Brandenburg in year 2002 at location Berge (Harvest: 03.09.2002)

		Variety	Silage maturity number	Dry matter yield	Dry matter content	Starch content	Energy content	Starch yield	Energy yield
				dt ha^{-1}	**%**	**%**	**MJ NEL kg^{-1}**	**dt ha^{-1}**	**GJ NEL ha^{-1}**
1	**X**	**Tassilo**	**S 200**	**167.9**	**36.6**	**35.2**	**6.73**	**59.0**	**112.9**
2	**X**	**Symphony**	**S 220**	**175.0**	**32.8**	**33.2**	**6.50**	**57.8**	**113.7**
3		**Pernel**	**S 190**	**177.2**	**36.2**	**34.4**	**6.64**	**61.0**	**117.7**
4	**X**	**Diplomat**	**S 210**	**190.4**	**36.0**	**34.2**	**6.69**	**64.9**	**127.3**
5	**X**	**Sagitta**	**S 210**	**169.8**	**34.5**	**38.6**	**6.68**	**65.3**	**113.2**
6		**Ravenna**	**S 210**	**168.1**	**37.3**	**39.2**	**6.68**	**65.9**	**112.2**
7		**Talman**	**S 210**	**180.9**	**35.4**	**34.7**	**6.52**	**62.7**	**117.9**
8		**Early Star**	**S 220**	**171.3**	**33.9**	**37.6**	**6.55**	**64.5**	**112.3**
9		**PR39P49**	**S 220**	**166.7**	**33.5**	**37.5**	**6.71**	**62.5**	**111.9**
10		**Nescio**	**S 220**	**186.0**	**33.3**	**36.9**	**6.64**	**68.7**	**123.5**
11		**Baxxos**	**S 210**	**184.4**	**36.7**	**37.9**	**6.66**	**70.1**	**122.9**
12		**Campesino**	**S 210**	**162.3**	**33.5**	**26.4**	**5.95**	**43.1**	**96.6**
13		**Viborg**	**S 210**	**177.2**	**35.3**	**32.3**	**6.30**	**57.1**	**111.6**
14		**Cascadas**	**S 220**	**183.0**	**33.4**	**38.9**	**6.48**	**71.3**	**118.6**
15		**Franz**	**S 220**	**177.9**	**34.1**	**30.7**	**6.30**	**54.7**	**112.1**
16		**Limit**	**S 220**	**170.8**	**31.6**	**34.0**	**6.36**	**58.1**	**108.6**
17		**Osorno**	**S 220**	**173.8**	**36.4**	**35.8**	**6.61**	**61.9**	**114.8**
18		**PR39H32**	**S 220**	**175.2**	**30.3**	**35.4**	**6.31**	**61.8**	**110.5**
19		**Ambros**	**S 220**	**186.7**	**34.9**	**33.4**	**6.67**	**62.4**	**124.4**
20		**PR39G12**	**ca. S 220**	**185.3**	**31.7**	**31.1**	**6.44**	**57.6**	**119.4**
	X	**average**		**175.8**	**35.0**	**35.3**	**6.65**	**61.8**	**116.8**
		average		**176.5**	**34.4**	**34.9**	**6.52**	**61.5**	**115.1**
LSD (α = 0.05)				**10.6**	**1.5**	**3.4**	**0.20**	**6.4**	**7.6**

X = Check variety LSD = Least significant difference of t-test

Table A2: Yield and quality parameters of silage maize of mid-early maturity group in regional variety trial of Brandenburg in year 2002 at location Berge (Harvest: 09.09.2002)

		Variety	Silage maturity number	Dry matter yield	Dry matter content	Starch content	Energy content	Starch yield	Energy yield
				dt ha^{-1}	**%**	**%**	**MJ NEL kg^{-1}**	**dt ha^{-1}**	**GJ NEL ha^{-1}**
1	**X**	**Probat**	**S 230**	**177.5**	**38.1**	**38.7**	**6.62**	**68.8**	**117.5**
2	**X**	**Fjord**	**S 240**	**182.3**	**40.6**	**36.6**	**6.74**	**66.6**	**122.7**
3	**X**	**Romario**	**ca. S 240**	**184.2**	**37.5**	**38.3**	**6.69**	**70.6**	**123.2**
4	**X**	**Eurostar**	**ca. S 240**	**199.2**	**37.1**	**38.1**	**6.64**	**76.0**	**132.3**
5	**X**	**Effekt**	**S 240**	**177.6**	**37.2**	**37.7**	**6.74**	**66.9**	**119.5**
6	**X**	**Rivaldo**	**S 240**	**180.0**	**37.6**	**37.8**	**6.66**	**67.8**	**119.9**
7		**Acapulco**	**S 230**	**188.1**	**36.5**	**38.9**	**6.65**	**73.1**	**124.9**
8		**Topper**	**S 230**	**180.8**	**39.2**	**41.8**	**6.85**	**75.5**	**123.7**
9		**LG3226**	**S 240**	**192.2**	**39.0**	**40.1**	**6.75**	**77.1**	**129.7**
10		**Veritis**	**S 240**	**186.3**	**37.5**	**35.6**	**6.50**	**66.2**	**120.8**
11		**Sandrina**	**S 250**	**186.2**	**35.1**	**33.6**	**6.38**	**62.5**	**118.8**
12		**Andino**	**S 230**	**182.0**	**41.1**	**37.8**	**6.54**	**68.9**	**119.1**
13		**Cingaro**	**S 230**	**149.9**	**36.7**	**28.2**	**6.05**	**42.5**	**90.9**
14		**Joxxal**	**S 230**	**175.9**	**37.9**	**36.0**	**6.44**	**63.4**	**113.2**
15		**Lacta**	**S 230**	**176.2**	**40.2**	**39.8**	**6.64**	**70.1**	**117.0**
16		**Milagro**	**S 230**	**189.8**	**40.6**	**39.3**	**6.75**	**74.6**	**128.0**
17		**Montello**	**S 230**	**175.4**	**38.6**	**38.3**	**6.58**	**67.0**	**115.4**
18		**Energystar**	**S 240**	**179.4**	**38.5**	**38.1**	**6.62**	**68.3**	**118.6**
19		**PR39B50**	**S 240**	**184.2**	**37.5**	**40.6**	**6.81**	**74.8**	**125.5**
20		**Pontos**	**S 250**	**172.3**	**37.9**	**37.6**	**6.59**	**64.7**	**113.3**
21		**Sampaio**	**S 230**	**180.4**	**41.6**	**35.9**	**6.53**	**64.7**	**117.7**
22		**Flavi**	**S 250**	**193.5**	**34.3**	**37.5**	**6.73**	**72.6**	**130.1**
	X	**average**		**183.5**	**38.0**	**37.9**	**6.68**	**69.5**	**122.5**
		average		**181.5**	**38.2**	**37.6**	**6.61**	**68.3**	**120.1**
LSD ($\alpha = 0.05$)				**10.9**	**2.2**	**2.9**	**0.19**	**6.8**	**7.9**

X = Check variety LSD = Least significant difference of t-test

Table A3: Yield and quality parameters of selected recommended silage maize varieties for Brandenburg area in year 2002 at location Berge

	Variety	Silage maturity number	Dry matter yield	Dry matter content	Starch content	Energy content	Starch yield	Energy yield
			dt ha^{-1}	**%**	**%**	**MJ NEL kg^{-1}**	**dt ha^{-1}**	**GJ NEL ha^{-1}**
Silage maturity numbers S 180 to S 220 (early)								
X	**Arsenal**	**S 210**	**169.1**	**38.1**	**36.8**	**6.77**	**62.3**	**114.5**
X	**Justina**	**S 210**	**165.4**	**35.6**	**32.4**	**6.56**	**53.6**	**108.6**
X	**Symphony**	**S 220**	**175.3**	**34.0**	**32.3**	**6.28**	**56.6**	**110.1**
X	**Dono**	**S 220**	**168.4**	**36.2**	**33.5**	**6.65**	**56.3**	**112.0**
X	**Monitor**	**S 220**	**170.4**	**36.3**	**28.5**	**6.59**	**48.5**	**112.2**
X	**Pedro**	**S 220**	**172.3**	**33.8**	**29.2**	**6.45**	**50.2**	**111.2**
X	**Oldham**	**S 220**	**174.0**	**41.4**	**37.2**	**6.63**	**64.6**	**115.3**
X	**average**		**170.7**	**36.5**	**32.8**	**6.56**	**56.0**	**112.0**
Silage maturity numbers S 230 to S 250 (mid-early)								
	Probat	**S 230**	**163.8**	**36.0**	**36.6**	**6.74**	**60.0**	**110.4**
	Caballero	**S 240**	**157.0**	**35.5**	**37.0**	**6.64**	**58.0**	**104.2**
	Domenico	**S 240**	**172.4**	**34.1**	**33.0**	**6.58**	**56.9**	**113.5**
	Banguy	**ca. S 240**	**143.2**	**34.9**	**31.1**	**6.68**	**44.6**	**95.7**
	Magister	**S 250**	**183.4**	**32.3**	**32.5**	**6.52**	**59.6**	**119.6**
average (maturity group)			**164.0**	**34.6**	**34.0**	**6.63**	**55.8**	**108.7**
Silage maturity numbers S 260 to S 280 (mid-late)								
	Liberal	**S 260**	**166.8**	**32.4**	**31.6**	**6.64**	**52.8**	**110.8**
	Prestige	**S 260**	**206.7**	**34.9**	**30.5**	**6.15**	**63.1**	**127.1**
	Atalante	**S 280**	**204.0**	**33.6**	**33.7**	**6.56**	**68.7**	**133.7**
average (maturity group)			**192.5**	**33.6**	**31.9**	**6.5**	**61.5**	**123.9**
FAO 750			**148.6**	**24.6**	**8.6**	**5.9**	**12.9**	**88.1**

Table A4: Yield and quality parameters of silage maize of early maturity group in regional variety trial of Brandenburg in year 2003 at location Berge (harvest: 15.08.2003)

		Variety	Silage maturity number	Dry matter yield	Dry matter content	Starch content	Energy content	Starch yield	Energy yield
				dt ha^{-1}	**%**	**%**	**MJ NEL kg^{-1}**	**dt ha^{-1}**	**GJ NEL ha^{-1}**
1	**X**	**Pernel**	**S 190**	**111.5**	**38.95**	**25.52**	**5.72**	**28.6**	**63.9**
2	**X**	**Tassilo**	**S 200**	**105.7**	**43.45**	**34.71**	**6.26**	**36.8**	**66.2**
3	**X**	**Symphony**	**S 220**	**100.1**	**38.58**	**28.61**	**5.82**	**28.6**	**58.2**
4	**X**	**Ravenna**	**S 210**	**99.7**	**40.95**	**34.91**	**6.22**	**34.9**	**62.0**
5	**X**	**Talman**	**S 210**	**103.9**	**43.13**	**34.32**	**6.18**	**35.8**	**64.2**
6	**X**	**Early Star**	**S 220**	**100.3**	**38.60**	**27.08**	**5.82**	**27.2**	**58.4**
7		**Baxxos**	**S 210**	**101.3**	**37.85**	**21.70**	**5.68**	**22.0**	**57.6**
8		**Cascadas**	**S 220**	**107.0**	**35.92**	**24.50**	**5.46**	**26.2**	**58.5**
9		**Nescio**	**S 220**	**113.1**	**41.70**	**36.08**	**6.41**	**40.8**	**72.4**
10		**PR39H32**	**S 220**	**99.1**	**34.60**	**21.28**	**5.57**	**21.2**	**55.0**
11		**Constantino**	**S 210**	**107.9**	**35.30**	**18.02**	**5.34**	**19.4**	**57.5**
12		**Spider**	**S 210**	**106.5**	**38.60**	**22.25**	**5.47**	**23.8**	**58.3**
13		**Aurelia**	**S 220**	**105.5**	**39.68**	**27.15**	**5.75**	**28.7**	**60.7**
14		**Delitop**	**S 220**	**117.6**	**40.80**	**30.91**	**6.07**	**36.3**	**71.3**
15	**X**	**Ambros**	**S 220**	**117.7**	**39.12**	**27.34**	**5.94**	**32.2**	**70.0**
16	**X**	**PR39G12**	**ca. S 220**	**104.7**	**38.82**	**29.77**	**5.89**	**31.4**	**61.8**
17		**Mikis**	**S 210**	**90.1**	**40.77**	**27.55**	**5.99**	**25.3**	**54.2**
18	**X**	**PR39P49**	**S 220**	**98.7**	**40.45**	**29.70**	**6.07**	**29.3**	**60.0**
	X	**average**		**104.7**	**40.23**	**30.22**	**5.99**	**31.6**	**62.7**
		average		**105.0**	**39.29**	**27.85**	**5.87**	**29.3**	**61.7**
LSD (α = 0.05)				**10.0**	**2.68**	**4.69**	**0.28**	**6.3**	**6.7**

X = Check variety

LSD = Least significant difference of t-test

Table A5: Yield and quality parameters of silage maize of mid-early maturity group in regional variety trial of Brandenburg in year 2003 at location Berge (harvest: 23.08.2003)

		Variety	Silage maturity number	Dry matter yield	Dry matter content	Starch content	Energy content	Starch yield	Energy yield
				dt ha^{-1}	**%**	**%**	**MJ NEL kg^{-1}**	**dt ha^{-1}**	**GJ NEL ha^{-1}**
1	**X**	**LG3226**	**S 240**	**135.5**	**47.80**	**31.26**	**5.99**	**42.4**	**81.1**
2	**X**	**Rivaldo**	**S 240**	**122.0**	**39.80**	**29.15**	**5.86**	**35.6**	**71.5**
3	**X**	**Sandrina**	**S 250**	**123.2**	**42.85**	**30.72**	**5.86**	**37.8**	**72.2**
4	**X**	**Acapulco**	**S 230**	**132.3**	**41.85**	**35.58**	**6.19**	**47.2**	**82.0**
5	**X**	**Topper**	**S 230**	**117.1**	**46.20**	**32.65**	**6.01**	**38.4**	**70.4**
6		**Joxxal**	**S 230**	**115.8**	**48.40**	**27.55**	**5.61**	**31.9**	**65.0**
7		**Lacta**	**S 230**	**134.4**	**44.50**	**34.71**	**6.10**	**46.7**	**82.0**
8		**Milagro**	**S 230**	**129.9**	**43.45**	**26.89**	**5.63**	**34.8**	**73.1**
9		**Montello**	**S 230**	**124.4**	**45.63**	**30.37**	**5.89**	**37.8**	**73.3**
10		**Energystar**	**S 240**	**127.0**	**43.15**	**31.82**	**5.97**	**40.6**	**76.0**
11		**PR39B50**	**S 240**	**118.0**	**47.20**	**33.25**	**6.03**	**39.2**	**71.1**
12		**Pontos**	**S 250**	**131.9**	**42.35**	**33.07**	**6.07**	**43.6**	**80.0**
13		**Coxximo**	**S 230**	**132.7**	**45.23**	**33.13**	**6.09**	**44.1**	**80.9**
14		**DK 231**	**S 230**	**115.8**	**44.60**	**29.94**	**5.75**	**34.7**	**66.6**
15		**DK 247**	**S 240**	**114.8**	**44.10**	**32.35**	**6.01**	**37.3**	**69.0**
16		**Korneli**	**S 240**	**125.1**	**43.48**	**31.30**	**5.95**	**39.2**	**74.4**
17		**LG3232**	**S 240**	**132.1**	**48.38**	**32.32**	**6.08**	**42.6**	**80.3**
18		**Positive**	**S 240**	**118.4**	**45.00**	**31.01**	**5.79**	**37.0**	**68.8**
19		**Sileno**	**S 240**	**119.3**	**43.00**	**31.12**	**5.85**	**37.2**	**69.9**
20		**Argentera**	**S 250**	**126.2**	**40.68**	**32.39**	**6.08**	**41.0**	**76.8**
21		**Arobase**	**S 250**	**135.7**	**41.88**	**31.42**	**5.96**	**42.7**	**81.0**
22		**Hexxer**	**S 250**	**126.5**	**40.80**	**30.61**	**6.04**	**38.5**	**76.2**
23		**PR39V62**	**S 250**	**126.9**	**40.73**	**35.04**	**6.20**	**44.4**	**78.7**
24		**Andino**	**S 230**	**122.1**	**42.63**	**30.06**	**5.77**	**36.7**	**70.4**
25	**X**	**Flavi**	**S 250**	**128.4**	**36.48**	**25.27**	**5.90**	**32.5**	**75.8**
	X	**average**		**126.4**	**42.50**	**30.77**	**5.97**	**39.0**	**75.5**
		average		**125.4**	**43.61**	**31.32**	**5.95**	**39.4**	**74.7**
LSD (α = 0.05)				**10.2**	**2.04**	**3.40**	**0.24**	**5.9**	**7.3**

X = Check variety LSD = Least significant difference of t-test (α=5 %)

Table A6: Yield and quality parameter of the recommended silage maize varieties for Brandenburg area (according to variety advisory for silage maize 2001 and 2002) in year 2003 at location Berge

	Variety	Silage maturity number	Dry matter yield	Dry matter content	Starch content	Energy content	Starch yield	Energy yield
			dt ha^{-1}	**%**	**%**	**MJ NEL kg^{-1}**	**dt ha^{-1}**	**GJ NEL ha^{-1}**
Silage maturity numbers S 180 to S 220 (early)								
X	**Arsenal**	**S 210**	**97.12**	**37.48**	**21.33**	**5.67**	**20.7**	**55.1**
	Diplomat	**S 210**	**106.57**	**39.53**	**21.20**	**5.41**	**22.6**	**57.7**
	Baxxos	**S 210**	**101.30**	**37.85**	**21.69**	**5.68**	**22.0**	**57.6**
X	**Justina**	**S 210**	**104.44**	**45.04**	**37.01**	**6.35**	**38.7**	**66.3**
	Ravenna	**S 210**	**99.70**	**40.95**	**34.91**	**6.22**	**34.8**	**62.0**
	Sagitta	**S 210**	**96.19**	**41.54**	**32.18**	**6.13**	**31.0**	**59.0**
	Talman	**S 210**	**103.90**	**43.13**	**34.32**	**6.18**	**35.8**	**64.2**
	Ambros	**S 220**	**117.70**	**39.12**	**27.34**	**5.94**	**32.2**	**70.0**
	Cascadas	**S 220**	**107.00**	**35.92**	**24.50**	**5.46**	**26.2**	**58.5**
X	**Symphony**	**S 220**	**100.10**	**38.58**	**28.61**	**5.82**	**28.5**	**58.2**
X	**Monitor**	**S 220**	**121.57**	**40.01**	**25.79**	**5.67**	**31.4**	**68.9**
	Nescio	**S 220**	**105.80**	**39.93**	**25.27**	**5.90**	**32.5**	**75.8**
X	**Pedro**	**S 220**	**130.29**	**41.87**	**21.92**	**5.60**	**28.6**	**73.0**
X	**Oldham**	**S 220**	**105.65**	**37.43**	**31.06**	**5.93**	**32.8**	**62.6**
	average		**106.95**	**39.88**	**27.65**	**5.85**	**29.8**	**63.5**
X	**average**		**109.86**	**40.07**	**27.62**	**5.84**	**30.1**	**64.0**
Silage maturity numbers S 230 to S 250 (mid-early)								
	Acapulco	**S 230**	**132.30**	**41.85**	**35.58**	**6.19**	**47.2**	**82.0**
X	**Probat**	**S 230**	**89.17**	**38.27**	**20.16**	**5.45**	**18.0**	**48.6**
x	**Topper**	**S 230**	**117.10**	**46.20**	**32.65**	**6.01**	**38.4**	**70.4**
X	**Caballero**	**S 240**	**101.10**	**35.58**	**19.83**	**5.32**	**20.0**	**53.8**
X	**Domenico**	**S 240**	**107.32**	**37.83**	**23.09**	**5.43**	**24.8**	**58.3**
	Effekt	**S 240**	**110.56**	**38.97**	**26.30**	**5.62**	**29.1**	**62.2**
	Eurostar	**S 240**	**92.18**	**34.84**	**17.64**	**5.37**	**16.3**	**49.5**
	Romario	**S 240**	**109.97**	**32.18**	**16.91**	**5.28**	**18.6**	**58.0**
	LG3226	**S 240**	**135.50**	**47.80**	**31.26**	**5.99**	**42.4**	**81.1**
X	**Banguy**	**ca. S 240**	**91.57**	**38.37**	**24.32**	**5.55**	**22.3**	**50.8**
x	**PR39B50**	**S 240**	**118.00**	**47.20**	**33.25**	**6.03**	**39.2**	**71.1**
X	**Magister**	**S 250**	**113.36**	**35.38**	**20.58**	**5.33**	**23.3**	**60.4**
	Pontos	**S 250**	**131.90**	**42.35**	**33.07**	**6.07**	**43.6**	**80.0**
	Flavi	**S 250**	**128.40**	**36.48**	**25.27**	**5.90**	**32.5**	**75.8**
	average		**112.75**	**39.52**	**25.71**	**5.68**	**29.7**	**64.4**
X	**average**		**105.37**	**39.83**	**24.84**	**5.59**	**26.6**	**59.1**
Silage maturity numbers S 260 to S 280 (mid-late)								
	Liberal	**S 260**	**105.93**	**32.91**	**15.24**	**5.35**	**16.1**	**56.6**
	Prestige	**S 260**	**80.73**	**32.69**	**17.80**	**5.51**	**14.4**	**44.5**
	average							
FAO 750			**96.45**	**23.31**	**2.00**	**4.67**	**1.9**	**45.1**

X = Variety. that was tested in years 2002 and 2003 (Core varieties)

Table A7: Yield and quality parameters of silage maize of early maturity group in regional variety trial of Brandenburg in year 2004 at location Berge (harvest: 06.09.2004)

		Variety	Silage maturity number	Dry matter yield	Dry matter content	Starch content	Energy content	Starch yield	Energy yield
				dt ha^{-1}	**%**	**%**	**MJ NEL kg^{-1}**	**dt ha^{-1}**	**GJ NEL ha^{-1}**
1	**X**	**Tassilo**	**S 200**	**154.0**	**30.3**	**30.9**	**6.40**	**47.6**	**98.6**
2		**Delitop**	**S 220**	**169.8**	**28.1**	**29.3**	**6.29**	**49.8**	**106.8**
3		**Apostrof**	**S 200**	**161.2**	**30.0**	**30.8**	**6.31**	**49.8**	**101.8**
4	**X**	**Baxxos**	**S 210**	**159.5**	**30.0**	**30.4**	**6.33**	**48.5**	**101.0**
5	**X**	**Nescio**	**S 220**	**160.4**	**27.7**	**33.3**	**6.46**	**53.5**	**103.6**
6		**Constantino**	**S 210**	**176.7**	**29.8**	**27.8**	**6.20**	**49.1**	**109.4**
7		**Amati**	**S 210**	**156.1**	**29.4**	**31.4**	**6.35**	**49.1**	**99.2**
8		**Auxxel**	**S 210**	**157.3**	**31.2**	**28.5**	**6.18**	**44.7**	**97.0**
9		**ES Arktis**	**S 210**	**168.7**	**29.9**	**31.1**	**6.16**	**52.4**	**103.9**
10		**Expert**	**S 210**	**178.9**	**31.1**	**29.7**	**6.20**	**53.1**	**110.9**
11		**Schiffer**	**S 210**	**165.3**	**28.0**	**32.9**	**6.42**	**54.4**	**106.2**
12		**Silas**	**S 210**	**171.2**	**29.4**	**34.1**	**6.41**	**58.4**	**109.8**
13		**Amadeo**	**S 220**	**179.2**	**28.4**	**32.4**	**6.38**	**58.1**	**114.3**
14		**Aurelia**	**S 220**	**182.3**	**31.1**	**27.7**	**6.20**	**50.4**	**113.0**
15		**LG3197**	**S 220**	**170.4**	**29.1**	**30.1**	**6.35**	**51.5**	**108.3**
16		**Spider**	**S 210**	**158.0**	**28.6**	**28.7**	**6.18**	**45.4**	**97.7**
	X	**average**		**158.0**	**29.3**	**31.5**	**6.40**	**49.9**	**101.1**
		average		**166.8**	**29.5**	**30.6**	**6.30**	**51.0**	**105.1**
LSD (α=0,05)				**12.9**	**1.4**	**2.9**	**0.19**	**6.7**	**9.2**

X = Check variety LSD = Lowest significant difference of t-test

Table A8: **Yield and quality parameters of silage maize of mid-early maturity group in regional variety trial of Brandenburg in year 2004 at location Berge (Harvest: 13.09.2004)**

		Variety	Silage maturity number	Dry matter yield	Dry matter content	Starch content	Energy content	Starch yield	Energy yield
				dt ha^{-1}	**%**	**%**	**MJ NEL kg^{-1}**	**dt ha^{-1}**	**GJ NEL ha^{-1}**
1	**X**	**Rivaldo**	**S 240**	**175.2**	**31.5**	**31.7**	**6.40**	**55.6**	**112.1**
2	**X**	**LG3226**	**S 240**	**177.1**	**31.5**	**31.6**	**6.36**	**55.9**	**112.6**
3		**Sileno**	**S 240**	**183.0**	**31.0**	**31.7**	**6.30**	**58.1**	**115.1**
4	**X**	**Topper**	**S 230**	**176.6**	**32.2**	**34.8**	**6.37**	**61.4**	**112.4**
5	**X**	**Lacta**	**S 230**	**185.1**	**34.2**	**33.2**	**6.17**	**61.7**	**114.3**
6	**X**	**PR39B50**	**S 240**	**175.8**	**31.4**	**35.4**	**6.40**	**62.2**	**112.4**
7		**Coxximo**	**S 230**	**184.5**	**32.7**	**28.4**	**6.03**	**52.4**	**111.3**
8		**DK 231**	**S 230**	**186.0**	**33.9**	**28.8**	**6.06**	**53.6**	**112.9**
9		**DK 247**	**S 240**	**187.0**	**32.9**	**32.0**	**6.14**	**59.7**	**114.8**
10		**LG3232**	**S 240**	**192.4**	**33.5**	**30.4**	**6.24**	**58.6**	**120.2**
11		**Argentera**	**S 250**	**177.9**	**29.9**	**28.0**	**6.15**	**49.9**	**109.4**
12		**Arobase**	**S 250**	**182.5**	**31.2**	**28.5**	**5.95**	**52.0**	**108.5**
13		**Hexxer**	**S 250**	**176.4**	**32.4**	**31.8**	**6.35**	**56.4**	**112.1**
14		**PR39V62**	**S 250**	**185.1**	**30.8**	**29.3**	**6.38**	**54.2**	**118.2**
15		**DKc2949**	**S 230**	**178.3**	**32.9**	**32.5**	**6.46**	**58.1**	**115.1**
16		**ES Limes**	**S 230**	**188.4**	**33.3**	**30.1**	**6.32**	**56.5**	**119.0**
17		**Goldosse**	**S 230**	**191.4**	**32.7**	**30.8**	**6.22**	**58.8**	**119.1**
18		**Agro Max**	**S 240**	**204.9**	**32.5**	**28.2**	**6.28**	**57.9**	**128.7**
19		**Deltastar**	**S 240**	**181.3**	**31.6**	**33.3**	**6.32**	**60.4**	**114.6**
20		**Nathan**	**S 240**	**204.1**	**31.8**	**28.6**	**6.42**	**58.5**	**131.1**
21		**PR39A98**	**S 240**	**184.2**	**32.3**	**32.9**	**6.35**	**60.5**	**116.8**
22		**Glinka**	**S 250**	**189.1**	**30.4**	**32.4**	**6.31**	**61.1**	**119.4**
23		**Maibi**	**S 250**	**198.1**	**32.0**	**31.6**	**6.35**	**62.5**	**125.7**
24		**NKLugan**	**S 250**	**195.6**	**29.7**	**27.7**	**6.16**	**54.2**	**120.4**
25	**X**	**Pontos**	**S 250**	**189.5**	**32.1**	**30.4**	**6.29**	**57.6**	**119.2**
	X	**average**		**179.9**	**32.1**	**32.9**	**6.33**	**59.1**	**113.8**
		average		**186.0**	**32.0**	**31.0**	**6.27**	**57.5**	**116.6**
LSD (α=0,05)				**15.0**	**1.4**	**3.2**	**0.23**	**7.8**	**10.9**

X = Check variety   AM = arithmetic mean   LSD = Least sign difference of t-tests (α=5 %)

Table A9: Yield and quality parameter of the recommended silage maize varieties for Brandenburg area (according to variety advisory for silage maize 2003 and 2004) in year 2004 at location Berge

Variety	Silage maturity number	Dry matter yield	Dry matter content	Starch content	Energy content	Starch yield	Energy yield
		dt ha^{-1}	**%**	**%**	**MJ NEL kg^{-1}**	**dt ha^{-1}**	**GJ NEL ha^{-1}**
Silage maturity numbers S 180 to S 220 (early)							
Arsenal	**S 210**	**172.5**	**287**	**29.72**	**6.19**	**51.3**	**106.7**
Justina	**S 210**	**146.7**	**261**	**33.14**	**6.40**	**48.6**	**93.9**
Nescio	**S 220**	**158.2**	**285**	**32.81**	**6.45**	**51.9**	**102.0**
Oldham	**S 220**	**168.4**	**277**	**36.73**	**6.60**	**61.9**	**111.2**
PR39P49	**S 220**	**158.9**	**270**	**28.34**	**6.16**	**45.0**	**97.9**
Ravenna	**S 210**	**166.8**	**310**	**37.50**	**6.64**	**62.6**	**110.8**
Sagitta	**S 210**	**146.0**	**257**	**39.07**	**6.71**	**57.0**	**97.9**
Symphony	**S 220**	**170.5**	**294**	**33.06**	**6.32**	**56.4**	**107.7**
Talman	**S 210**	**163.5**	**294**	**32.87**	**6.43**	**53.7**	**105.1**
Ambros	**S 220**	**161.4**	**269**	**27.00**	**6.15**	**43.6**	**99.3**
Diplomat	**S 210**	**161.6**	**294**	**31.20**	**6.43**	**50.4**	**103.9**
PR39G12	**S 220**	**168.6**	**262**	**35.90**	**6.51**	**60.5**	**109.7**
average		**161.9**	**280**	**33.11**	**6.41**	**53.6**	**103.8**
Silage maturity numbers S 230 to S 250 (mid-early)							
Banguy	**S 240**	**188.6**	**307**	**27.39**	**6.54**	**51.7**	**123.3**
LG3226	**S 240**	**195.0**	**317**	**32.75**	**6.80**	**63.9**	**132.6**
Acapulco	**S 230**	**189.4**	**297**	**29.16**	**6.43**	**55.2**	**121.8**
Romario	**S 240**	**191.7**	**315**	**29.38**	**6.57**	**56.3**	**126.0**
Eurostar	**S 240**	**188.8**	**304**	**29.43**	**6.56**	**55.6**	**123.8**
Effekt	**S 240**	**190.8**	**294**	**29.07**	**6.49**	**55.5**	**123.8**
Magister	**S 250**	**180.2**	**269**	**26.28**	**6.52**	**47.4**	**117.5**
Topper	**S 230**	**177.5**	**317**	**34.41**	**6.79**	**61.1**	**120.6**
Probat	**S 230**	**165.4**	**289**	**29.74**	**6.51**	**49.2**	**107.6**
Caballero	**S 240**	**171.6**	**292**	**34.05**	**6.69**	**58.4**	**114.8**
Pontos	**S 250**	**164.9**	**279**	**31.71**	**6.53**	**52.3**	**107.7**
PR39B50	**S 240**	**193.1**	**300**	**31.54**	**6.61**	**60.9**	**127.7**
Lacta	**S 230**	**173.5**	**309**	**30.89**	**6.38**	**53.6**	**110.7**
Flavi	**S 250**	**190.1**	**273**	**25.59**	**6.48**	**48.6**	**123.2**
average		**182.9**	**297**	**30.10**	**6.56**	**55.0**	**120.1**
Silage maturity numbers S 260 to S 280 (mid-late)							
Liberal	**S 260**	**191.3**	**272**	**22.57**	**6.38**	**43.2**	**122.1**
Prestige	**ca. S 260**	**184.9**	**294**	**24.41**	**6.28**	**45.1**	**116.1**
Monumental	**S 260**	**185.1**	**295**	**28.31**	**6.75**	**52.4**	**125.0**
average	**AM**	**187.1**	**287**	**25.10**	**6.47**	**46.9**	**121.1**

X = Variety. that was tested in years 2002 and 2003 (Core varieties) AM = arithmetic mean (maturity group)

Table A10: Leaf area index of early maturity group using LAI 2000

Variety	Date			
	22.07.02	**31.07.02**	**07.08.02**	**15.08.02**
X Tassilo	**2.82**	**2.90**	**3.16**	**3.10**
X Symphony	**3.53**	**3.73**	**3.91**	**3.95**
Pernel	**3.13**	**3.21**	**3.39**	**3.45**
X Diplomat	**3.13**	**3.22**	**3.40**	**3.51**
X Sagitta	**2.54**	**3.53**	**3.67**	**3.70**
Ravenna	**2.93**	**3.03**	**3.21**	**3.28**
Talman	**3.27**	**3.55**	**3.61**	**3.46**
Early Star	**3.18**	**3.20**	**3.42**	**3.43**
PR39P49	**3.13**	**3.12**	**3.42**	**3.53**
Nescio	**3.38**	**3.41**	**3.48**	**3.72**
Baxxos	**3.10**	**3.09**	**3.37**	**3.41**
Campesino	**2.99**	**3.16**	**3.31**	**3.41**
Viborg	**3.08**	**3.13**	**3.28**	**3.27**
Cascadas	**3.15**	**3.25**	**3.35**	**3.45**
Franz	**3.37**	**3.32**	**3.68**	**3.68**
Limit	**3.46**	**3.51**	**3.76**	**3.90**
Osorno	**3.22**	**3.26**	**3.49**	**3.37**
PR39H32	**3.31**	**3.33**	**3.56**	**3.88**
Ambros	**3.23**	**3.24**	**3.58**	**3.64**
PR39G12	**3.17**	**3.28**	**3.50**	**3.47**
X Average	**3.26**	**3.35**	**3.53**	**3.57**
Average (n = 20)	**3.21**	**3.27**	**3.48**	**3.53**
LSD (α =5 %)	**0.28**	**0.27**	**0.30**	**0.32**

Table A11: Leaf area index of check varieties using LAI 2000

Variety	Date			
	22.07.02	**31.07.02**	**07.08.02**	**15.08.02**
Arsenal	**3.4**	**3.3**	**3.0**	**2.8**
Banguy	**3.3**	**2.9**	**2.7**	**2.6**
Caballero	**3.1**	**3.6**	**3.2**	**3.1**
Domenico	**3.3**	**3.2**	**3.0**	**3.0**
Dono	**3.4**	**3.3**	**3.3**	**3.2**
Justina	**3.7**	**3.2**	**2.8**	**2.9**
Magister	**3.6**	**3.4**	**3.6**	**3.4**
Monitor	**3.2**	**3.1**	**3.1**	**3.1**
Oldham	**3.2**	**3.1**	**2.9**	**3.0**
Pedro	**3.3**	**3.3**	**3.1**	**3.1**
Probat	**3.3**	**2.9**	**2.8**	**2.6**
Symphony	**4.0**	**3.8**	**3.4**	**3.3**
Average (n = 12)	**3.4**	**3.3**	**3.1**	**3.0**

Table A12: Leaf area index of mid-early maturity group using LAI 2000

Variety	Date			
	22.07.02	**31.07.02**	**07.08.02**	**15.08.02**
X Probat	**3.03**	**3.19**	**3.12**	**3.17**
X Fjord	**3.32**	**3.41**	**3.46**	**3.57**
X Romario	**3.12**	**3.32**	**3.31**	**3.49**
X Eurostar	**3.37**	**3.54**	**3.39**	**3.67**
X Effekt	**3.39**	**3.62**	**3.51**	**3.59**
X Rivaldo	**3.15**	**3.32**	**3.22**	**3.34**
Acapulco	**3.18**	**3.37**	**3.27**	**3.42**
Topper	**3.12**	**3.53**	**3.43**	**3.67**
LG3226	**3.21**	**3.33**	**3.28**	**3.26**
Veritis	**3.60**	**3.65**	**3.66**	**3.71**
Sandrina	**3.27**	**3.37**	**3.45**	**3.13**
Andino	**3.19**	**3.35**	**3.35**	**3.48**
Cingaro	**2.98**	**3.22**	**2.94**	**3.18**
Joxxal	**3.24**	**3.33**	**3.26**	**3.26**
Lacta	**3.06**	**3.10**	**3.16**	**3.26**
Milagro	**3.33**	**3.35**	**3.37**	**3.52**
Montello	**3.21**	**3.45**	**3.29**	**3.40**
Energystar	**2.95**	**3.15**	**3.08**	**3.24**
PR39B50	**3.07**	**3.29**	**3.29**	**3.51**
Pontos	**3.23**	**3.37**	**3.35**	**3.59**
Sampaio	**3.13**	**3.31**	**3.33**	**3.33**
Flavi	**3.11**	**3.20**	**3.33**	**3.47**
X Average	**3.23**	**3.40**	**3.33**	**3.47**
Average	**3.20**	**3.35**	**3.31**	**3.42**
LSD (α = 5 %)	**0.23**	**0.25**	**0.27**	**0.39**
Atalante	**3.9**	**3.2**	**3.2**	**3.3**
FAO 750	**3.9**	**3.8**	**3.2**	**3.5**
Liberal	**3.7**	**3.7**	**4.0**	**3.7**
Prestige	**3.8**	**3.8**	**3.8**	**3.6**
Average (n = 4)	**3.8**	**3.6**	**3.6**	**3.5**

Table A13: Leaf area index of early maturity varieties with LAI 2000 plant canopy analyser in 2003

Variety	Date								
	18.06.	25.06.	03.07.	08.07.	15.07.	24.07.	29.07.	8.08.	12.08.
Pernel	**1.82**	**2.22**	**2.74**	**3.06**	**3.18**	**2.28**	**2.32**	**1.32**	**0.81**
Tassilo	**1.55**	**2.03**	**2.56**	**2.90**	**2.67**	**2.13**	**2.18**	**1.28**	**0.71**
Symphony	**1.92**	**2.48**	**2.92**	**3.05**	**3.11**	**2.53**	**2.41**	**1.49**	**0.89**
Ravenna	**1.96**	**2.22**	**2.74**	**2.89**	**2.80**	**2.46**	**2.31**	**1.39**	**0.80**
Talman	**1.67**	**2.16**	**2.83**	**2.75**	**2.88**	**2.54**	**2.31**	**1.24**	**0.62**
Early Star	**1.68**	**2.07**	**2.52**	**2.99**	**2.96**	**2.35**	**2.21**	**1.33**	**0.90**
Baxxos	**1.67**	**2.13**	**2.72**	**2.90**	**2.99**	**2.31**	**2.19**	**1.43**	**0.89**
Cascadas	**1.8**	**2.19**	**2.53**	**2.89**	**3.02**	**2.59**	**2.36**	**1.36**	**1.03**
Nescio	**2.04**	**2.51**	**2.78**	**2.91**	**3.38**	**2.62**	**2.41**	**1.53**	**0.89**
PR39H32	**2.01**	**2.45**	**2.54**	**2.75**	**2.86**	**2.21**	**2.21**	**1.37**	**0.73**
Constantin	**1.82**	**2.24**	**2.44**	**2.86**	**2.56**	**2.14**	**2.01**	**1.49**	**0.94**
Spider	**1.83**	**2.26**	**2.52**	**2.85**	**2.63**	**2.35**	**2.19**	**1.24**	**0.73**
Aurelia	**2.03**	**2.55**	**3.06**	**2.96**	**2.95**	**2.55**	**2.35**	**1.44**	**0.82**
Delitop	**1.69**	**2.37**	**2.98**	**3.04**	**3.21**	**2.60**	**2.62**	**1.58**	**0.99**
Ambros	**1.66**	**2.13**	**2.47**	**2.88**	**2.82**	**2.57**	**2.54**	**1.40**	**0.78**
PR39G12	**1.95**	**2.4**	**2.74**	**2.85**	**3.04**	**2.40**	**2.00**	**1.28**	**0.80**
Mikis	**1.75**	**2.24**	**2.75**	**2.63**	**3.31**	**2.52**	**2.26**	**1.47**	**0.69**
PR39P49	**1.99**	**2.34**	**2.69**	**2.93**	**3.11**	**2.56**	**2.34**	**1.28**	**0.91**
Average (n = 18)	**1.82**	**2.28**	**2.70**	**2.89**	**2.97**	**2.43**	**2.29**	**1.38**	**0.83**
LSD (α = 5%)	**0.21**	**0.17**	**0.22**	**0.24**	**0.45**	**0.43**	**0.24**	**0.16**	**0.31**

Table A14: Leaf area index of mid-early maturity varieties with LAI 2000 plant canopy analyser in 2003

Variety	Date									
	18.06	25.06	03.07.	08.07.	15.07.	24.07.	29.07.	08.08.	12.08.	18.08.
LG 3226	**1.76**	**2.40**	**2.86**	**3.17**	**3.35**	**3.67**	**2.83**	**1.91**	**0.95**	**0.87**
Rivaldo	**1.80**	**2.39**	**3.01**	**3.14**	**3.39**	**3.52**	**2.85**	**2.23**	**1.48**	**1.27**
Sandrina	**2.04**	**2.29**	**2.85**	**3.28**	**3.43**	**3.57**	**3.16**	**1.94**	**1.31**	**1.06**
Acapulco	**1.83**	**2.38**	**2.83**	**2.92**	**3.26**	**3.59**	**2.77**	**2.03**	**1.25**	**1.02**
Topper	**2.07**	**2.57**	**3.06**	**3.34**	**3.71**	**3.68**	**3.42**	**2.33**	**1.20**	**1.06**
Joxxal	**2.04**	**2.51**	**3.01**	**3.31**	**3.54**	**3.51**	**3.19**	**2.43**	**1.35**	**0.97**
Lacta	**2.03**	**2.32**	**2.95**	**3.21**	**3.44**	**3.80**	**3.12**	**2.31**	**1.22**	**0.97**
Milagro	**2.00**	**2.35**	**2.92**	**3.09**	**3.17**	**3.63**	**3.41**	**2.42**	**1.45**	**1.08**
Montello	**1.98**	**2.27**	**2.96**	**3.25**	**3.38**	**3.64**	**3.19**	**2.16**	**1.47**	**1.18**
Energystar	**1.85**	**2.37**	**2.58**	**2.95**	**3.20**	**3.36**	**2.88**	**1.88**	**1.17**	**0.93**
PR39B50	**2.00**	**2.35**	**2.90**	**3.24**	**3.48**	**3.24**	**2.91**	**2.21**	**1.16**	**0.88**
Pontos	**1.79**	**2.41**	**2.92**	**3.24**	**3.58**	**3.87**	**3.17**	**2.26**	**1.62**	**1.36**
Coxximo	**1.88**	**2.33**	**2.88**	**3.11**	**3.30**	**3.20**	**2.86**	**1.55**	**1.06**	**1.06**
DK 231	**2.10**	**2.37**	**3.25**	**3.31**	**3.51**	**3.50**	**3.15**	**2.03**	**1.28**	**0.99**
DK 247	**1.95**	**2.18**	**2.77**	**3.23**	**3.39**	**3.62**	**2.83**	**2.03**	**1.27**	**0.95**
Korneli	**1.94**	**2.27**	**3.03**	**3.27**	**3.63**	**3.57**	**3.20**	**2.36**	**1.38**	**1.18**
LG3232	**1.75**	**2.32**	**2.88**	**2.93**	**3.55**	**3.62**	**3.41**	**2.11**	**0.95**	**0.89**
Positive	**1.78**	**2.26**	**2.84**	**2.97**	**3.29**	**3.39**	**2.84**	**2.25**	**1.23**	**0.84**
Sileno	**1.91**	**2.62**	**2.8**	**2.96**	**3.35**	**3.73**	**3.15**	**2.22**	**1.14**	**0.92**
Argentera	**2.04**	**2.55**	**3.28**	**3.67**	**3.93**	**3.89**	**3.50**	**2.59**	**1.60**	**1.10**
Arobase	**1.76**	**2.2**	**2.55**	**3.03**	**3.10**	**3.45**	**3.22**	**2.34**	**1.33**	**1.20**
Hexxer	**1.70**	**2.19**	**2.66**	**2.92**	**3.10**	**2.80**	**2.48**	**1.87**	**1.13**	**1.16**
PR39V62	**1.73**	**2.43**	**2.82**	**3.14**	**3.44**	**3.64**	**3.24**	**2.43**	**1.61**	**1.06**
Andino	**1.75**	**2.46**	**2.67**	**2.93**	**3.31**	**3.48**	**3.22**	**2.40**	**1.28**	**0.96**
Flavi	**2.01**	**2.43**	**2.91**	**3.03**	**3.28**	**3.38**	**2.95**	**1.83**	**1.32**	**1.18**
Average (n = 25)	**1.90**	**2.37**	**2.89**	**3.15**	**3.40**	**3.53**	**3.08**	**2.16**	**1.29**	**1.05**
LSD (α = 0.05)	**0.18**	**0.30**	**0.28**	**0.30**	**0.29**	**0.31**	**0.47**	**0.44**	**0.22**	**0.16**

Table A15: Leaf area of individual leaves (cm²) for early maturity group (2002)

Variety	Leaf generation																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Tassilo	5	10	20	45	90	153	242	349	455	495	496	442	395	270	143	44		
Symphony	6	13	30	59	112	217	339	474	497	531	474	404	235	147				
Pernel	5	12	28	52	105	151	254	402	474	527	501	412	351	257	112			
Diplomat	7	15	30	57	109	199	296	438	535	551	503	459	359	260	169	95		
Sagitta	6	13	25	45	107	191	300	427	545	589	563	494	352	270	117			
Ravenna	6	13	30	55	125	211	360	464	523	531	479	365	221	181				
Talman	7	18	46	86	174	320	476	582	602	553	452	313	171	94				
Early Star	5	10	26	52	104	179	290	418	531	597	577	523	460	348	171	45		
PR39P49	5	12	27	59	127	241	431	598	700	692	630	505	305	119				
Nescio	6	12	27	54	111	204	401	576	627	627	590	510	360	152	9			
Baxxos	6	14	30	57	123	195	338	501	537	573	495	438	331	174	27			
Campesino	6	12	33	72	130	224	330	514	604	666	696	606	556	489	419	254	133	56
Viborg	6	15	37	74	162	263	441	583	620	600	544	430	252	116	90			
Cascades	6	15	26	72	163	278	408	548	627	629	562	481	364	231	112	26		
Franz	6	13	28	56	124	215	343	462	542	569	580	523	400	274	146			
Limit	5	8	17	45	90	153	255	423	554	575	544	517	464	361	209	123		
Osorno	6	12	27	56	98	161	273	373	447	553	564	508	449	344	262	156		
PR39H32	5	14	30	76	171	278	448	665	735	750	673	618	464	197				
Ambros	6	13	25	53	100	187	314	440	513	567	524	459	382	283	129			
PR39G12	5	12	24	49	101	168	299	465	628	727	679	631	513	359	147			
Average (n = 20)	6	13	28	59	121	209	342	485	565	595	556	482	369	246	151	106	133	56
Arsenal	3	9	20	41	93	169	336	505	642	630	611	518	435	262	102			
Banguy	5	12	17	46	87	152	217	363	447	460	480	395	230	131				
Caballero	5	11	26	51	106	242	359	551	582	655	634	523	330	143				
Domenico	7	8	31	61	117	219	316	399	558	530	526	454	310	137				
Dono	5	10	17	37	72	123	180	323	428	644	485	418	276	43				
Justina	5	14	33	85	193	338	505	560	614	656	470	417	187					
Magister	6	13	29	70	106	241	389	560	687	606	585	477	323	205				
Monitor	8	12	24	57	94	154	335	491	589	646	544	487	309	153				
Oldham	5	12	30	59	138	260	402	541	608	564	551	481	260					
Pedro	5	7	17	40	67	125	244	337	486	575	581	479	456	422	357	301	159	67
Probat	4	14	23	53	97	218	317	419	496	576	553	503	309	106				
Symphony	6	11	26	56	126	212	322	442	441	502	440	361	228	80				
Average (n = 12)	5	11	24	55	108	204	327	458	548	587	538	459	304	168	229	301	159	67

Table A16: Leaf area of individual leaves (cm²) for mid-early maturity group (2002)

Variety	Leaf generation																		
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**
Probat	**4**	**11**	**19**	**46**	**94**	**188**	**292**	**446**	**568**	**613**	**572**	**474**	**362**	**191**					
Fjord	**6**	**12**	**32**	**66**	**123**	**204**	**294**	**428**	**489**	**539**	**504**	**446**	**350**	**204**	**301**	**123**			
Romario	**7**	**14**	**32**	**56**	**119**	**227**	**291**	**462**	**575**	**605**	**619**	**525**	**438**	**299**	**153**				
Eurostar	**7**	**15**	**30**	**58**	**126**	**234**	**341**	**538**	**688**	**743**	**721**	**653**	**565**	**478**	**336**	**152**			
Effekt	**5**	**14**	**30**	**73**	**169**	**302**	**428**	**591**	**653**	**667**	**600**	**512**	**374**	**214**	**150**				
Rivaldo	**7**	**14**	**35**	**69**	**132**	**232**	**353**	**470**	**565**	**573**	**575**	**477**	**385**	**217**	**123**				
Acapulco	**7**	**12**	**32**	**75**	**142**	**225**	**379**	**529**	**591**	**582**	**517**	**436**	**352**	**273**	**94**				
Topper	**6**	**15**	**32**	**60**	**127**	**238**	**333**	**439**	**558**	**561**	**488**	**428**	**266**	**157**					
LG3226	**7**	**14**	**32**	**61**	**122**	**198**	**355**	**513**	**609**	**654**	**646**	**564**	**366**	**285**	**185**	**120**			
Veritis	**8**	**15**	**31**	**65**	**133**	**228**	**357**	**510**	**616**	**643**	**600**	**585**	**500**	**413**	**292**	**111**	**31**		
Sandrina	**5**	**13**	**28**	**58**	**123**	**232**	**334**	**502**	**619**	**654**	**656**	**607**	**507**	**342**	**152**				
Andino	**6**	**13**	**30**	**70**	**131**	**227**	**324**	**466**	**547**	**591**	**571**	**523**	**459**	**386**	**258**	**118**	**113**		
Cingaro	**6**	**13**	**33**	**71**	**145**	**260**	**385**	**548**	**624**	**651**	**613**	**550**	**488**	**394**	**278**	**160**	**118**		
Joxxal	**6**	**13**	**26**	**48**	**93**	**175**	**257**	**369**	**510**	**602**	**629**	**554**	**418**	**286**	**169**	**43**			
Lacta	**7**	**16**	**37**	**79**	**156**	**302**	**389**	**508**	**546**	**563**	**505**	**450**	**318**	**157**					
Milagro	**6**	**13**	**28**	**58**	**100**	**183**	**307**	**471**	**579**	**621**	**581**	**474**	**326**	**252**	**102**				
Montello	**7**	**16**	**38**	**68**	**136**	**225**	**338**	**459**	**579**	**626**	**615**	**486**	**370**	**335**	**193**	**89**			
Energystar	**6**	**13**	**51**	**55**	**100**	**179**	**281**	**426**	**553**	**558**	**548**	**479**	**367**	**263**	**140**				
PR39B50	**6**	**13**	**30**	**58**	**112**	**221**	**333**	**498**	**592**	**616**	**580**	**508**	**357**	**160**	**190**	**187**			
Pontos	**6**	**16**	**29**	**71**	**143**	**226**	**366**	**477**	**567**	**610**	**596**	**527**	**470**	**327**	**170**	**79**			
Sampaio	**6**	**13**	**29**	**69**	**142**	**229**	**357**	**462**	**588**	**652**	**628**	**547**	**454**	**376**	**261**	**138**	**100**		
Flavi	**5**	**11**	**29**	**53**	**111**	**192**	**326**	**451**	**562**	**617**	**598**	**540**	**451**	**357**	**181**				
Average	**6**	**14**	**32**	**63**	**126**	**224**	**337**	**480**	**581**	**616**	**589**	**516**	**406**	**289**	**196**	**120**	**90**		
N = 22																			
Atalante	**5**	**12**	**24**	**57**	**86**	**160**	**275**	**363**	**489**	**495**	**512**	**431**	**396**	**264**					
FAO 750	**5**	**13**	**21**	**46**	**94**	**117**	**212**	**344**	**461**	**601**	**730**	**687**	**652**	**579**	**483**	**396**	**348**	**277**	**156**
Liberal	**9**	**17**	**39**	**71**	**116**	**178**	**320**	**489**	**589**	**679**	**740**	**635**	**540**	**419**	**262**	**89**			
Prestige	**10**	**18**	**39**	**61**	**117**	**188**	**320**	**516**	**659**	**726**	**729**	**626**	**497**	**454**	**270**				
Average (n = 4)	**8**	**15**	**31**	**59**	**103**	**161**	**282**	**428**	**550**	**625**	**678**	**595**	**521**	**429**	**338**	**242**	**348**	**277**	**156**

Table A17 **Average sum of leaf area (cm²) and leaf number from cob leaf position of early maturity varieties of forage maize at harvest time in 2002 at location Berge (03.09.02)**

Variety	Leaf location in relation to cob position													Sum LA	Leaf no.
	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7		
Tassilo		**158**	**318**	**426**	**503**	**490**	**455**	**408**	**319**	**179**	**69**			**3325**	**10**
Symphony		**24**	**149**	**339**	**461**	**497**	**531**	**480**	**404**	**235**	**147**			**3267**	**10**
Pernel		**78**	**254**	**402**	**486**	**527**	**501**	**412**	**351**	**257**	**112**			**3380**	**10**
Diplomat		**98**	**276**	**401**	**527**	**574**	**502**	**476**	**398**	**286**	**193**	**87**		**3818**	**11**
Sagitta			**270**	**402**	**539**	**588**	**581**	**524**	**393**	**247**	**117**			**3661**	**9**
Ravenna			**211**	**360**	**494**	**517**	**522**	**479**	**365**	**221**	**181**			**3350**	**9**
Talman		**38**	**277**	**429**	**583**	**615**	**555**	**499**	**340**	**212**	**114**			**3662**	**10**
Early Star			**133**	**418**	**526**	**597**	**575**	**523**	**460**	**348**	**171**	**45**		**3796**	**10**
PR39P49			**291**	**468**	**653**	**705**	**663**	**600**	**462**	**251**	**186**			**4279**	**9**
Nescio		**33**	**109**	**401**	**567**	**641**	**618**	**607**	**510**	**257**	**152**			**3895**	**10**
Baxxos			**46**	**306**	**439**	**514**	**563**	**509**	**453**	**361**	**139**	**13**		**3343**	**10**
Campesino		**180**	**474**	**586**	**697**	**681**	**616**	**570**	**499**	**403**	**214**	**86**	**56**	**5062**	**12**
Viborg		**73**	**190**	**484**	**600**	**630**	**585**	**504**	**401**	**206**	**77**			**3750**	**10**
Cascadas		**210**	**367**	**511**	**609**	**632**	**581**	**509**	**392**	**280**	**119**	**26**		**4236**	**11**
Franz		**61**	**269**	**399**	**515**	**588**	**562**	**570**	**469**	**350**	**194**	**102**		**4079**	**11**
Limit		**44**	**255**	**423**	**557**	**587**	**544**	**517**	**464**	**361**	**209**	**123**		**4084**	**11**
Osorno	**42**	**167**	**291**	**374**	**501**	**552**	**549**	**510**	**391**	**321**	**108**			**3806**	**11**
PR39H32		**215**	**340**	**615**	**721**	**769**	**683**	**643**	**499**	**262**	**129**			**4876**	**10**
Ambros			**166**	**349**	**456**	**529**	**568**	**502**	**444**	**354**	**245**	**63**		**3676**	**10**
PR39G12		**191**	**424**	**573**	**728**	**672**	**645**	**533**	**413**	**203**	**162**			**4544**	**10**

(0) cob leaf position

(-1) leaf generation below cob leaf

(+1) leaf generation above cob leaf

Table A18 **Average sum of leaf area (cm²) and leaf number from cob leaf position of mid-early maturity varieties of forage maize at harvest time in 2002 at location Berge (09.09.02)**

Variety	Leaf location in relation to cob position												Sum LA	Leaf number
	-5	-4	-3	-2	-1	0	1	2	3	4	5	6		
Probat		**53**	**165**	**362**	**530**	**580**	**594**	**531**	**439**	**297**	**133**		**3684**	**10**
Fjord			**97**	**161**	**340**	**508**	**533**	**510**	**422**	**322**	**187**	**143**	**3223**	**10**
Romario		**59**	**208**	**439**	**539**	**590**	**632**	**550**	**468**	**360**	**164**		**4009**	**10**
Eurostar		**70**	**330**	**593**	**691**	**740**	**710**	**634**	**565**	**435**	**297**	**154**	**5219**	**11**
Effekt	**39**	**137**	**406**	**535**	**662**	**662**	**616**	**541**	**442**	**249**	**150**		**4439**	**11**
Rivaldo		**35**	**223**	**295**	**548**	**581**	**592**	**526**	**446**	**312**	**138**		**3696**	**10**
Acapulco		**166**	**391**	**548**	**603**	**580**	**503**	**436**	**367**	**202**	**94**		**3890**	**10**
Topper			**183**	**373**	**459**	**559**	**568**	**503**	**436**	**299**	**181**		**3561**	**9**
LG 3226			**74**	**283**	**627**	**647**	**618**	**566**	**349**	**262**	**140**		**3566**	**9**
Veritis			**107**	**433**	**637**	**640**	**581**	**574**	**486**	**393**	**257**	**59**	**4167**	**10**
Sandrina		**284**	**517**	**625**	**648**	**680**	**608**	**507**	**343**	**153**			**4365**	**9**
Andino			**169**	**352**	**584**	**585**	**545**	**494**	**418**	**333**	**196**	**79**	**3755**	**10**
Cingaro	**64**	**166**	**356**	**619**	**651**	**621**	**575**	**495**	**422**	**305**	**193**	**127**	**4594**	**12**
Joxxal		**51**	**312**	**411**	**542**	**626**	**617**	**537**	**431**	**277**	**115**	**43**	**3962**	**11**
Lacta	**29**	**54**	**68**	**320**	**380**	**572**	**535**	**485**	**411**	**217**	**126**		**3197**	**11**
Milagro		**125**	**294**	**452**	**576**	**619**	**592**	**527**	**393**	**309**	**158**	**192**	**4237**	**11**
Montello		**183**	**264**	**507**	**598**	**625**	**637**	**515**	**385**	**290**	**118**		**4122**	**10**
Energy Star		**39**	**109**	**392**	**482**	**593**	**541**	**534**	**419**	**317**	**225**	**126**	**3777**	**11**
PR39B50		**107**	**263**	**249**	**446**	**622**	**581**	**513**	**369**	**160**	**190**	**187**	**3687**	**11**
Pontos			**269**	**515**	**580**	**607**	**584**	**488**	**404**	**245**	**129**		**3821**	**9**
Sampaio	**48**	**79**	**328**	**534**	**627**	**664**	**573**	**508**	**425**	**333**	**133**	**58**	**4310**	**12**
Flavi	**25**	**164**	**380**	**490**	**607**	**579**	**592**	**489**	**416**	**225**	**123**		**4090**	**11**

Table A19 **Average sum of leaf area (cm²) and leaf number from cob leaf position of early maturity varieties of forage maize at harvest time in 2003 at location Berge (12.08.03)**

Variety	Leaf location in relation to cob position									Sum LA	Leaf number
	-2	-1	0	1	2	3	4	5	6		
Pernel				**240**	**396**	**301**	**275**	**173**	**75**	**1460**	**6**
Tassilo		**202**	**249**	**444**	**430**	**338**	**263**	**164**	**76**	**2166**	**8**
Symphony			**118**	**408**	**360**	**210**	**165**	**60**		**1321**	**6**
Ravenna			**114**	**269**	**353**	**307**	**178**	**187**	**24**	**1432**	**7**
Talman				**400**	**235**	**194**	**152**	**50**		**1031**	**5**
Early Star				**329**	**329**	**247**	**267**	**203**	**93**	**1468**	**6**
Baxxos				**133**	**370**	**237**	**221**	**69**		**1030**	**5**
Cascadas			**131**	**211**	**481**	**387**	**331**	**258**	**92**	**1891**	**7**
Nescio				**119**	**551**	**453**	**249**	**77**		**1449**	**5**
PR39H32			**147**	**278**	**651**	**530**	**361**	**253**		**2220**	**6**
Constantino	**128**	**149**	**343**	**535**	**438**	**340**	**245**	**159**	**71**	**2408**	**9**
Spider				**321**	**224**	**434**	**318**	**191**	**98**	**1586**	**6**
Aurelia				**296**	**294**	**297**	**303**	**85**		**1275**	**5**
Delitop		**131**	**172**	**359**	**554**	**476**	**371**	**234**	**114**	**2411**	**8**
Ambros			**214**	**310**	**309**	**242**	**177**	**116**	**83**	**1451**	**7**
PR39G12			**400**	**632**	**554**	**423**	**253**	**139**		**2401**	**6**
Mikis				**142**	**290**	**255**	**311**	**165**		**1163**	**5**
PR39P49				**403**	**406**	**418**	**166**	**67**		**1460**	**5**

Table A20 Average sum of leaf area (cm²) and leaf number from cob leaf position of mid-early maturity varieties of forage maize at harvest time in 2003 at location Berge (18.08.03)

Variety	Leaf location in relation to cob position									Sum LA	Leaf number
	-1	0	1	2	3	4	5	6	7		
LG3226	9	119	252	280	302	263	123	55		1403	8
Rivaldo		72	200	357	410	323	193	109		1664	7
Sandrina		85	524	411	367	217	73			1677	6
Acapulco			178	222	319	174	109			1002	5
Topper			326	313	199	147	144	65		1194	6
Joxxal		80	282	285	181	143	11			982	6
Lacta	90	97	263	388	415	235	64			1552	7
Milagro	128	259	455	483	391	379	239	57		2391	8
Montello		159	313	273	207	206	75	43		1276	7
Energystar			158	147	350	217	148	72		1092	6
PR39B50		75	166	200	312	188	71			1012	6
Pontos	89	322	263	319	409	307	190			1899	7
Coxximo		241	294	488	449	354	202	119	8	2155	8
DK 231		205	164	251	293	79	38			1030	6
DK 247			83	213	266	159	78			799	5
Korneli			333	289	286	297	266	74		1545	6
LG3232		218	325	389	313	222	130	122		1719	7
Positive			371	264	303	291	111			1340	5
Sileno			174	425	246	163	55			1063	5
Argentera		275	225	454	446	345	125	17		1887	7
Arobase	94	111	255	556	372	322	258	111		2079	8
Hexxer	114	37	244	476	529	419	340	225	97	2481	9
PR39V62	118	160	244	438	383	222	193	168		1926	8
Andino		86	319	207	156	126	67	56		1017	7
Flavi	280	251	421	466	494	301	167			2380	7

(0) cob leaf position

(-1) leaf generation below cob leaf

(+1) leaf generation above cob leaf

Eidesstattliche Erklärung

Hiermit erkläre ich, Patrick Nixon Edoka, geboren am 04.11.1958 in Lira (Uganda), an Eides statt, dass ich diese Arbeit selbstständig und nur unter Zuhilfenahme der ausgewiesenen Mittel angefertigt habe.

Patrick Nixon Edoka

Appreciation

I would like to appreciate Prof. Dr Richter for giving me the opportunity to carry out my research work under his department. I am thankful for the patience that was involved and the guidance.

Thank you, Dr K. Schmaler, for your tireless support in this research, both in the field and in the office, without which it would have taken longer to accomplish the work than expected.

I also recall a well coordinated team work with Mr.V.Günther, Mrs. Plaßman and the entire team of Berge Research station, under Mr. Krüger and Mr. Richert, who contributed positively towards this work.

A very special thanks go to my family: my wonderful wife Solomy and my children: Kenan, Amira, Patricia, Immanuel and Abraham, for their prayers and encouragement. I thank God for Solid Rock Foundation Ministries and above all, for my Lord Jesus Christ, who strengthens me, to whom all glory and praise belong.